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BENCH SCALE FIXATION OF SOILS FROM THE TACOMA TAR PITS SUPERFUND SITE

FINAL REPORT

by

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Environmental Monitoring Systems
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16. ABSTRACT

This report documents the results of Bench-scale soil fixation study conducted with materials from the Tacoma Tar Pits Superfund Site. Chemical fixation (also called stabilization/solidification) is a relatively new technique for remediating contaminated soils. It entails both immobilization of contaminants via sorption or chemical reaction and physical transformation of the soil into a firm, impervious "monolith." Fixation has been used for years to immobilize metals in low-level radioactive wastes and specialized industrial wastes, such as baghouse dusts. It has not been commonly used at sites with organic contamination, however. This study utilized materials contaminated with metals and several types of organic contaminants including benzene, toluene, xylene, polycyclic aromatic hydrocarbons, and poloychlorinated biphenyls. Samples of heavily contaminated soils and wastes from the site were chemically fixed using a proprietary product, and the resulting monoliths were subjected to various physical, chemical, and leaching tests. The purpose was to assess the efficacy of fixation for a complicated matrix, i.e., one that was physically heterogeneous and contained several classes of contaminants.

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INTRODUCTION

Background of the Treatability Study

This report documents the results of a bench-scale soil fixation study conducted with materials from the Tacoma Tar Pits Superfund Site. Chemical fixation (also called stabilization/solidification) is a relatively new technique for remediating contaminated soils. It entails both immobilization of contaminants via sorption or chemical reaction and physical transformation of the soil into a firm, impervious "monolith." Fixation has been used for years to immobilize metals in low-level radioactive wastes and specialized industrial wastes, such as baghouse dusts. It has not been used for sites with organic contamination, however. A number of studies have shown less-than-satisfactory results from fixation of soils heavily contaminated with oil, grease, or organic solvents. These substances can seriously inhibit the cementing reactions essential to the formation of an impermeable monolith (Cullinane *et al.*, 1986). Thus, site-specific testing is required before fixation can be applied with confidence at sites with serious organic contamination.

The Tar Pits treatability study utilized materials contaminated with metals and several types of organic pollutants. Samples of heavily contaminated soils and wastes from the site were chemically fixed using a proprietary product, and the resulting monoliths were subjected to various physical, chemical, and leaching tests. The purpose was to assess the efficacy of fixation for a complicated matrix, i.e., one that was physically heterogeneous and contained several classes of contaminants. The study was part of a research program conducted by EPA's Region 10. Bench- and pilot-scale soil fixation have been carried out at several Superfund sites in the region. EPA's Environmental Monitoring Systems Laboratory (Las Vegas) provides overall direction for the program.

The Tar Pits Site

The Tar Pits site is located in Tacoma, Washington, on what was once the delta of the Puyallup River. The area is adjacent to Commencement Bay, and was covered with fill and developed for heavy industry early in this century. The Tar Pits Site (also known as the Tacoma Historical Coal Gasification Site) is about 30 acres in extent. A coal gasification plant was operated on the site from 1924 until 1956. The Washington Natural Gas Company owned the facility at the time of its closure and demolished it in 1965-1966. Most of the site was purchased by Joseph Simon & Sons, which has operated a scrap metal recycling facility there since 1967.

Current features of the site are shown in Figure 1. A sewer main corridor borders the site on the southeast. The southwestern boundary is a Burlington Northern Railroad right-of-way. To the northwest, the site is bordered by the Hygrade Meat Packing Plant, and the northeastern border parallels the Puyallup River. Most of the site is occupied by the metal recycling yard. There is also a natural gas transfer station on the site.

Wastes from the coal gasification and metal recycling operations are found over the entire site. A shallow pit at the southern corner of the site (the "tar pit") is filled with coal tar. Part of the recycling yard is known as the "tar boil area": tar bubbles to the surface of the ground following truck traffic or in hot weather. Two shallow ponds on the site are reported to have a layer of tar-derived contaminants beneath the water. The total estimated volume of tar on site is 5,000 cubic yards. Throughout the site, at shallow depths within the fill, are thin lenses of organic liquid known as "non-aqueous-phase liquid," or NAPL. Several acres are covered to

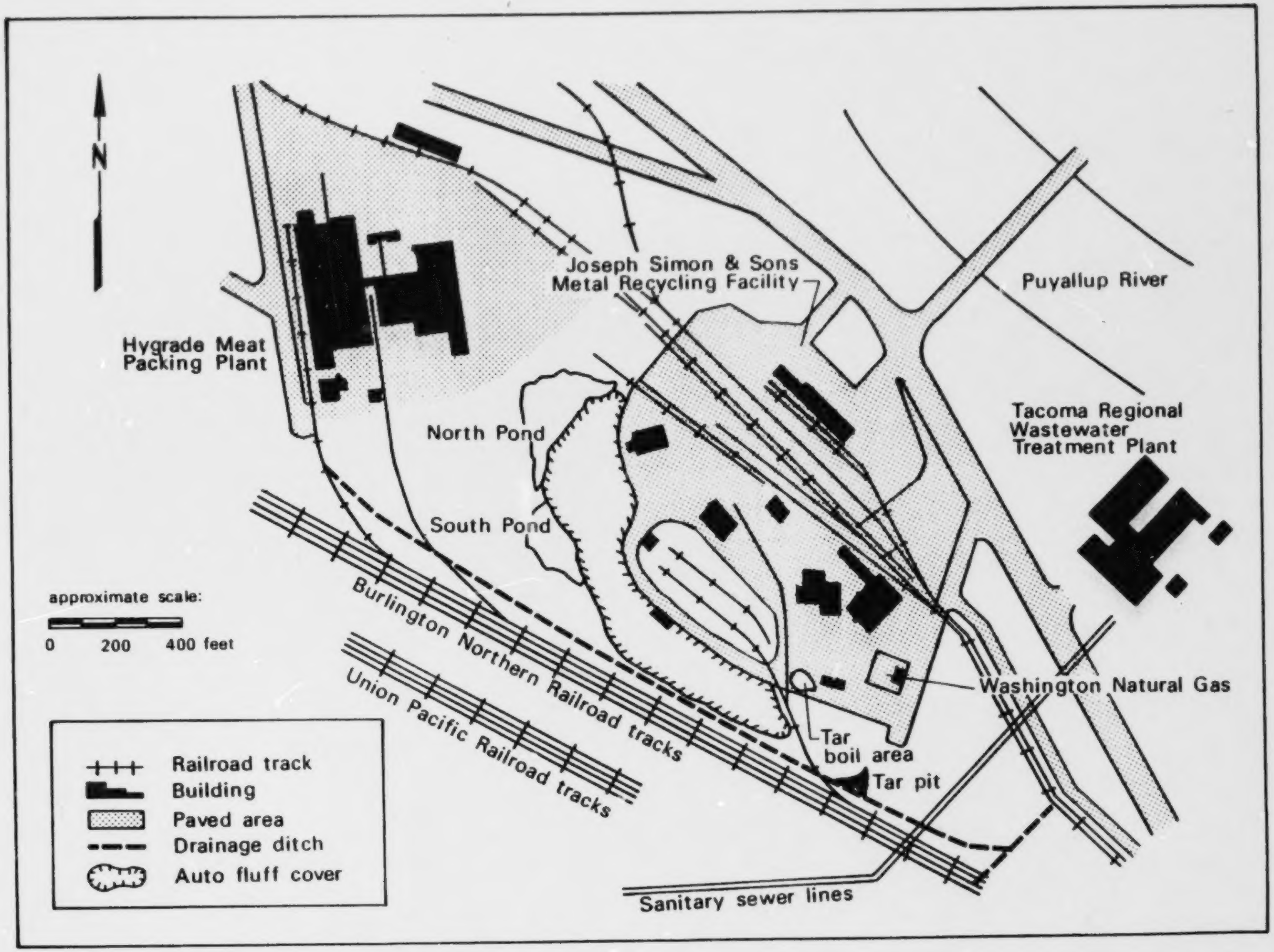

N
Joseph Simon & Sons Metal Recycling Facility
Puyallup River
Hygrade Meat Packing Plant
Tacoma Regional Wastewater Treatment Plant
North Pond
South Pond
approximate scale:
0 200 400 feet
Burlington Northern Railroad tracks
Union Pacific Railroad tracks
Washington Natural Gas
Tar boil area
Tar pit
Sanitary sewer lines
Railroad track
Building
Paved area
Drainage ditch
Auto fluff cover

Figure 1. The Tacoma Tar Pits Site.

a depth of 1-3 feet with decaying "auto fluff," the foam, rubber, and non-ferrous metal products of an automobile shredder. Other debris, including metallic scrap and building rubble, is mixed with the fluff.

Several classes of contaminants are documented from the site (AGI, 1987). Phenols, benzenes, and polycyclic aromatic hydrocarbons (PAHs) are the chief components of the coal tar and NAPL found on the site. In the auto fluff and underlying fill, metal concentrations (chiefly arsenic, mercury and lead) are elevated. PCBs are also found in the fluff and shallow fill, and they are present discontinuously at depths greater than five feet in the fill. PCB concentrations vary widely. Within the fill there is a shallow perched aquifer, continuous with the two ponds, during the winter months. Varying levels of metals, PAHs, phenols and benzenes have been measured in the shallow groundwater. A complete description of the site and the known contamination is given in the Remedial Investigation report (AGI 1987).

Regulatory Status of the Site

The Tar Pits site was identified as a potential CERCLA site in a 1981 EPA survey of the Commencement Bay-Nearshore Tideflats area. Initial site characterization took place from 1981 through 1983. Simon & Sons, Burlington Northern Railroad, Washington Natural Gas Company, and Hygrade Food Products Corporation were named potentially responsible parties (PRPs). The Remedial Investigation was conducted in 1984-1986 by Applied Geotechnology, Inc., on behalf of the PRPs. A Risk Assessment and Feasibility Study were performed by Envirosphere Company; the final Feasibility Study report was issued in 1987 (Envirosphere, 1987). The Record of Decision for the Tar Pits Site was signed on December 30, 1987. No consent decree had been signed as of February 1989.

The Feasibility Study considered a number of remedial alternatives for the site and identified *in situ* soil fixation as the most promising strategy. Soil fixation would entail excavating shallow fill and the overlying auto fluff to a total depth of 1 to 3 feet. The material would be mixed on site with a sorbent, a cementing agent, and water and replaced in the excavation. The fixed mixture would set up as a monolith about two feet thick and 15 acres in extent. An asphalt cap would be placed atop the monolith, and fences and runoff-runon control structures would be erected.

The Record of Decision followed the feasibility study in naming fixation as the preferred remedial alternative. The chosen alternative includes "...excavation of the most severely contaminated soils, stabilization of these soils using a technique which immobilizes contaminants, capping of the stabilized material (with asphalt), treatment of the surface water, continued groundwater monitoring, regulatory controls on water usage for both surface and groundwater, and restrictions on site access" (U.S. EPA, 1987a). In the Record of Decision cleanup goals for the site were established for four classes of contaminants: lead, benzene, PCBs, and PAHs. These goals are shown in Table 1.

Table 1. Cleanup Goal Performance Standards, Tacoma Tar Pits Site

From: Record of Decision (U.S. EPA 1987)

Contaminant or Contaminant Class	Soils (mg/kg)	Surface Water Boundary (μg/l)	Surface Water On-Site (μg/l)	Groundwater (sand and fill aquifers)(μg/l)
Lead	166[b]	3.2[d]	172[g]	50[h]
Benzene	56[c]	53[e]	5,300[g]	53[e]
PCBs	1.0[c]	0.2[d]	2[g]	0.2[d]
PAHs[a]	1.0[c]	5-30[f]	219[g]	5-30[f]

a. Sum of concentrations of benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo (k)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-c,d)pyrene.

b. Acceptable concentration.

c. 10^{-6} Risk Level for cancer, as determined by the site Risk Assessment.

d. Chronic freshwater ambient water quality criterion. Performance based on detection limit.

e. Acute freshwater ambient water quality criterion x 1/100.

f. Estimated range of chronic freshwater ambient water quality criterion based on marine criteria.

g. Estimated acute freshwater ambient water quality criterion.

h. Drinking Water MCL.

MATERIALS AND METHODS

The methods to be used in the bench fixation study were set forth in a detailed protocol prepared by MSI Detoxification, Inc. (1988). The protocol covers field activities, the fixation trials, and all materials handling, analytical methods, data interpretation, and quality assurance elements of the study. The protocol discusses in detail the rationale for sampling and experimental design.

Field Methods

Field sampling was conducted January 19-21, 1988, by EPA Region 10 personnel. The sampling design was deliberately biased towards the collection of highly-contaminated materials that would challenge the fixation reagents. Sampling locations were selected based on information generated during the Remedial Investigation. Sampling locations are shown in Figure 2. Soil samples were collected near the southern corner of the site. In this area, hand tools were used to excavate seven one-foot-deep pits. The subsample from each pit consisted of a slice of the pit wall one foot deep, eight inches wide, and three inches deep. The seven subsamples were screened through 3/8-inch hardware cloth and composited on-site in a shallow plywood box. From the well-mixed composite, 14 one-gallon glass jars were filled by placing a scoop of earth in each jar, in sequence. A smaller jar, to be used for soil chemical analysis, was also filled at this time. In all, about 150 lbs. of soil were collected.

VOA vials were filled with soil by pressing them into the walls of two soil pits. However, these samples were not used because the septa could not be seated properly atop the filled vials. The larger samples were subsampled in the laboratory for VOA analysis.

Two one-gallon glass jars were filled with coal tar. The tar was scooped from the tar pit with a shovel and poured into the sample jars, after the crust atop the tar pit had been scraped away.

Auto fluff was sampled from four locations along a curved transect between the ponds and the scrap yard (see Figure 2). At each location, a shovel was used to dig to the base of the fluff (about two feet). Depth-integrated samples from the four locations were passed through a clean 3/8-inch screen and mixed in a wood box. Sample containers (18 one-gallon glass jars, a 5-gallon plastic pail, and a 16-ounce glass jar) were filled with a trowel by placing one scoop of fluff in each container until all were full.

All samples were placed on ice as soon as they were collected. They were transported the same day to the EPA Region 10 laboratory at Manchester, Washington, where they were stored at approximately 40°F until the fixation trials.

Full-scale soil fixation at the Tar Pits would require processing materials much less uniform than soil, e.g., auto fluff and the associated heterogeneous debris. Therefore, a day was spent excavating and photographing these surficial materials at six locations across the site, to derive a simple classification according to size and material type.

Bench Fixation Trials

The raw-material samples were processed at the Manchester Laboratory January 25-26, 1988. Processing was performed by personnel from EPA Region 10, MDI, and Silicate Technology Corporation (STC), the vendor of the proprietary fixation reagents used.

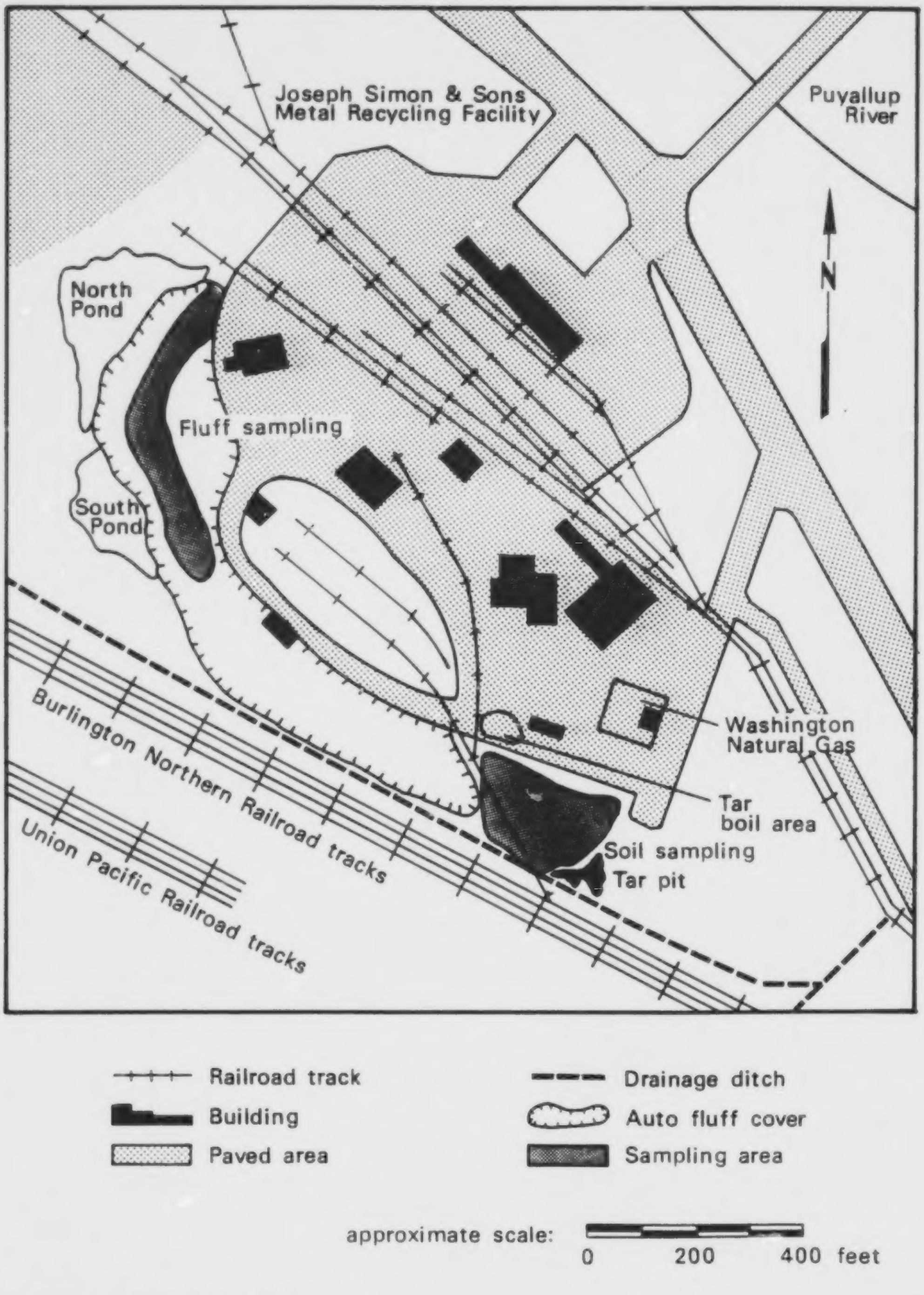

Joseph Simon & Sons
Metal Recycling Facility
Puyallup
River
N
North
Pond
South
Pond
Fluff sampling
Washington
Natural Gas
Tar
boil area
Soil sampling
Tar pit
Burlington Northern Railroad tracks
Union Pacific Railroad tracks
Railroad track
Building
Paved area
Drainage ditch
Auto fluff cover
Sampling area
approximate scale:
0
200
400 feet

Figure 2. Sampling Locations.

Prior to fixation, the field moisture contents of the soil and auto fluff were determined. This was done by drying two-kilogram portions of each material to a constant weight at 103°C.

The materials that were fixed were:

- pure soil
- 1:1 soil:auto fluff
- 3:1 soil:auto fluff (3 sets of samples)
- pure coal tar
- 1:1 soil:tar
- sand (clean commercial sand)

The materials were processed in two-kilogram batches. All mixtures were on a weight:weight basis. Field-moist materials were weighed on a triple-beam balance and mixed in a Hobart rotary mixer having a stainless-steel bowl of one-gallon capacity.

Each type of raw or mixed material was first sampled for chemical analysis and for TCLP extraction. Separate containers were filled for TCLP extraction and for analysis of phenols, volatile organics, semi-volatiles and PCBs, and metals. The samples were labeled, stored on ice and dispatched to the analytical laboratories via overnight courier. Analytical laboratories were chosen through the Contract Laboratory Program.

As sampled, the coal tar was extremely viscous and difficult to handle. Prior to mixing and fixation, it was warmed overnight in a hot-water bath under a fume hood to improve its handling properties. No attempt was made to capture or quantify escaping volatiles.

Before sample fixation was begun, STC personnel conducted two trial runs with different proportions of sample, water, and reagents. The appropriate mixture was selected based on the thickness (and ease of handling) of the final wet mixture. Because of the high concentrations of organic compounds in the samples, a high reagent:sample ratio was used; no trials were conducted to determine the minimum effective reagent concentrations (the Optimum Mix of Record). The same proportions of materials were used when fixing soil, fluff, and sand samples. The tar and tar:soil samples called for different proportions of materials and an additional reagent to sorb the organic compounds. The general procedure followed was:

1. Weigh out two kilograms of raw material and mix for one minute at medium speed in the Hobart mixer.

2. Add a small volume of liquid "activator solution" and mix two more minutes.

3. Add a measured volume of tap water and begin mixing again.

4. Add a weighed quantity of dry reagent while mixing for 10 minutes.

5. Pour mixture into molds. Tap filled molds gently on table to force out air bubbles.

6. Label each mold with a sample tag. Store in covered trays at 100 percent relative humidity.

Because of the requirements of the various tests, three sizes of cylindrical molds were used for the fixed materials. Each type of fixed mixture was used to fill three PVC molds 3 inches in diameter and 5 inches high, eight plexiglass molds 2 inches in diameter and 3 inches high, and two teflon molds 1 inch in diameter and 3 inches high.

Tests of Materials

Immediately after fixation, the large cylinders were shipped to the physical-testing laboratory to begin strength testing. The other cylinders of fixed materials were allowed to set up for 28 days before being analyzed or leached. They were stored in closed trays at 100 percent relative humidity, at ambient temperature (40°-55°F).

Figure 3 shows the disposition of all samples of raw and fixed material. The tests performed included chemical composition analysis, tests of physical/engineering properties, and leaching tests.

Chemical analyses of solid samples and leachates were performed by the Manchester Laboratory and various contract laboratories, according to CLP protocols. Analytical specifications are listed in Table 2. The suite of analytes was chosen on the basis of the known site contamination, suggested clean-up standards for the site (Table 1), and parameters that are more generally named in Applicable or Relevant and Appropriate Requirements (ARARs). In addition, it was desired to assess the success of fixation in immobilizing a wide range of contaminants. The specified detection limits were based on the cleanup goals for this site, or CLP Contract Required Detection Limits (contaminants for which goals were not established).

U.S. EPA's Center Hill Laboratory in Cincinnati, Ohio, performed physical/engineering tests according to protocols it has developed for chemically-fixed soils. Unconfined compressive strength was tested via a soil-cement protocol (a modification of ASTM D 1633-84). Each type of fixed sample was tested for "ultimate strength" after curing for 29 days. In addition, the development of strength was monitored by testing triplicate cylinders of the 3:1 soil-fluff mix at 3, 7, 14, 22, and 29 days after fixation. Permeability of cured cylinders was tested in a pressurized up-flow apparatus using 0.01 N calcium sulfate leachant. Each test was continued until a steady-state condition was achieved (i.e., calculated permeabilities stabilized within 10 percent). This procedure was developed by the Center Hill Laboratory especially for chemically-stabilized soils; it is very similar to EPA Method 9100-2.8, "Saturated hydraulic conductivity, saturated leachate conductivity, and intrinsic permeability" from SW-846 (U.S. EPA, 1986a). Durability was examined via a wet/dry stress test that is a modification of ASTM D-559 (Center Hill, 1989). In this test, the cylinders were alternately immersed in deionized water for 6 hours and air-dried at 60°F for 18 hours. After 10 cycles, a final weight was determined and compared to the initial weight to determine if material weathered from the cylinder. Seasonal wet/dry exposure of the full-scale monolith via shallow groundwater could be expected at the Tar Pits site, and this might influence the strength and permeability of the monolith. Therefore, after wet/dry stressing one set of fixed samples was subjected to compressive strength tests, and a second set was tested for permeability.

Two leaching tests were performed. Both raw and fixed materials were leached according to the Toxicity Characteristic Leaching Procedure (U.S. EPA, 1986b). This test, under development by the EPA, is meant to characterize a wide variety of contaminants; it is increasingly cited when ARARs are developed for Superfund sites. The TCLP is a batch extraction test utilizing finely-ground sample material. TCLP extractions of unfixed materials from the Tar Pits were begun soon after the materials were mixed. A set of fixed samples that had cured for 100 days was also crushed and extracted. The parameters listed in Table 2 were analyzed in the extracts. TCLP testing of the Tar Pits samples utilized standard and zero-headspace extractors.

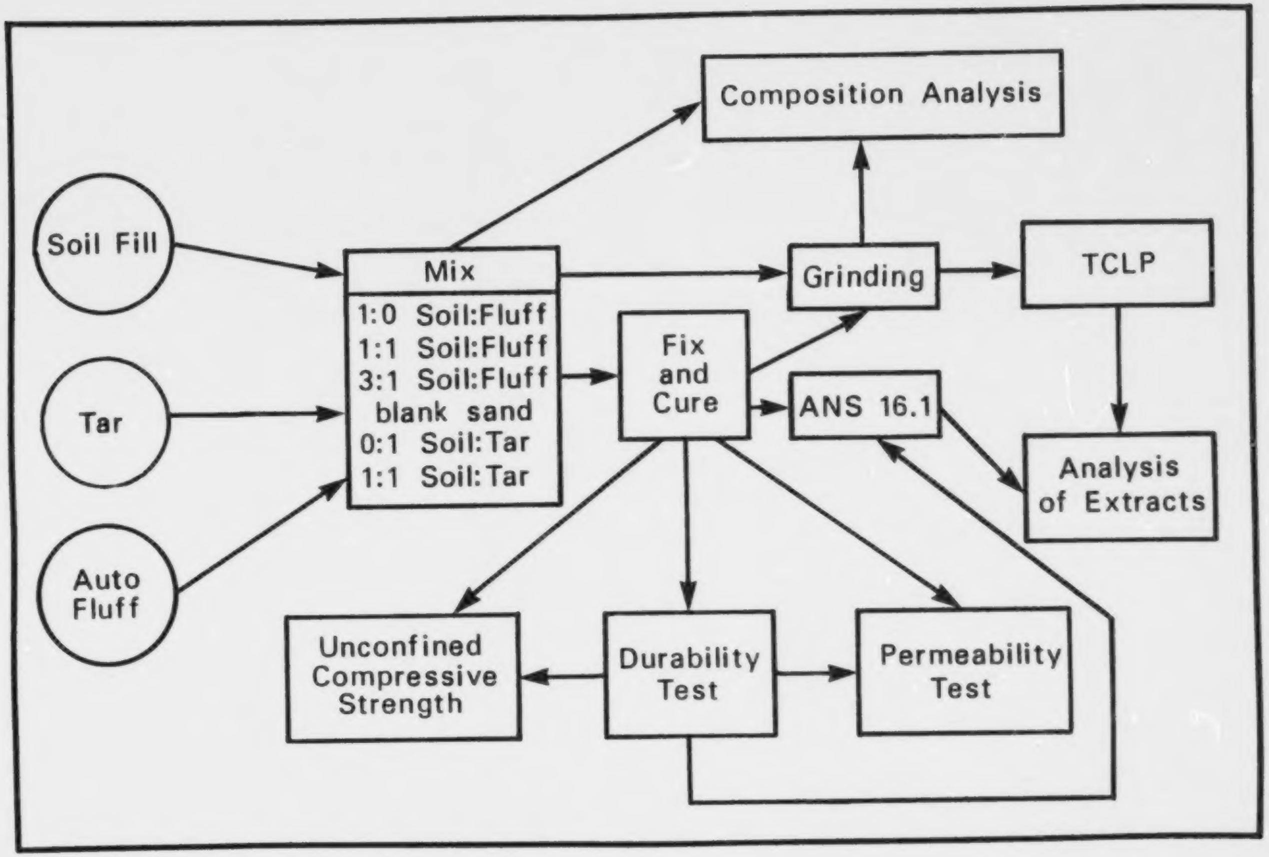

Soil Fill
Tar
Auto Fluff
Mix
1:0 Soil:Fluff
1:1 Soil:Fluff
3:1 Soil:Fluff
blank sand
0:1 Soil:Tar
1:1 Soil:Tar
Composition Analysis
Grinding
TCLP
Fix and Cure
ANS 16.1
Analysis of Extracts
Unconfined Compressive Strength
Durability Test
Permeability Test

Figure 3. Material flow through the testing procedure.

Table 2. Chemical Analytical Specifications

Parameter	Detection Method[a]	Specified Detection Limit Solids (mg/kg)	 Leachates (μg/L)
Arsenic	AA	10	10
Cadmium	ICP	100	5
Chromium	ICP	100	10
Copper	ICP	100	25
Lead	ICP	100	5
Mercury	cold vapor	1	0.2
Selenium	AA	10	5
Silver	AA	100	10
Zinc	ICP	100	20
PCBs (Seven Arochlors)	GC/MS	1	0.5
Total PAHs	HPLC,GC/MS	1	10
Benzene, Toluene and Xylene	GC/MS	50	5
Phenols	Colorimetry	1	10

[a] Contract Laboratory Program specifications (U.S. EPA 1987b,c).

The second extraction was a modification of American Nuclear Society Test 16.1. This test was specifically developed for chemically-fixed materials (ANS, 1986). For the ANS 16.1 test, small cylinders of fixed material were suspended in deionized water under quiescent conditions. After 1, 3, 5, 7, 14, 28, and 90 days, fresh water was substituted for the "old" leachant, which was subjected to chemical analysis (including pH and conductivity). A full set of fixed materials was tested this way. In addition, five cylinders of 3:1 soil-fluff were subjected to a combination of wet/dry stressing and ANS leaching. In these tests, wet/dry stressing of 4, 12, or 20 cycles was followed by standard ANS leaching. The objective was to find whether the cycles of immersion and drying influenced leachability of any contaminants. Between wet/dry stressing and ANS leaching, the cylinders were suspended out of the water for 2-4 days. Thus the effective stressing periods were 6, 14, and 24 days for the 4-, 12-, and 20-cycle tests, respectively.

The complete TCLP and ANS 16.1 protocols are appended to the project protocol (MDI 1988), which also discusses in detail the rationale for selection of the various tests and analyses.

Quality Assurance/Quality Control

Field procedures followed the guidelines set forth in the first edition of the Soil Sampling Quality Assurance User's Guide (Barth and Mason, 1984). They included steps to prevent cross-contamination, to create uniform, homogeneous composites of materials for the various tests, to collect sufficient material to allow for breakage and replication, and to document field activities according to standard CERCLA prescriptions.

Chemical analyses were performed according to CLP protocols (see the CLP Statements of Work for Organics and Inorganics, U.S. EPA, 1987b, c). The physical and engineering tests were conducted according to standard procedures developed by EPA's Center Hill Laboratory (Center Hill, 1989), which are based on the ASTM standard methods for determining strength and durability of concrete and permeability of soil. All of the leaching tests were conducted by the EPA's Manchester Laboratory, which is certified to perform TCLP extractions (ANS 16.1 is not widely used, and there is no certification procedure for this test). Sand blanks were tested alongside site materials in both types of extractions.

Data quality objectives for this project are described in the project protocol (MDI, 1988). All chemical composition data generated during the project were validated by consultants to U.S. EPA Region 10, according to CLP standards (U.S. EPA, 1987b, c). A small number of chemical values were judged unusable on the basis of QA/QC shortcomings. A number of values were flagged as "estimated" because instrument calibration standards, spikes, or surrogate sample results were outside CLP-mandated control limits. Slight exceedances of recommended holding times for mercury and organic analytes caused many results to be flagged as estimated. Many organic values were flagged as estimates because they fell between the mass spectrometer detection and quantitation limits. In interpreting analytical data, care was taken not to draw rigorous quantitative conclusions where data quality did not support such conclusions.

It was originally planned to fix and test mixtures of site soil and auto fluff, which are the only materials proposed for fixation in the Record of Decision. Shortly before the trials, it was decided to also sample and test coal tar. The testing yielded valuable information about the behavior and effects of volatile compounds in fixed mixtures. No attempt was made to measure or contain escaping volatiles at any stage, and mass balances for volatiles were not developed.

Sample Tracking and Documentation

The various materials and samples handled during the project were tracked as follows: The large jars of soil, fluff, and tar were labeled in the field according to their contents but were not given sample numbers. In creating samples, no distinction was made among jars of one type; it was assumed that each material collected in the field had been homogenized enough there that the contents of all jars were identical. Numbered samples were created at the time fixation was carried out. From each type of material, these samples were created:

- 6 containers of raw material (for analysis of VOAs, phenols, metals, PAHs and PCBs, for TCLP extraction, and to archive)
- 2 small fixed monoliths (ANS 16.1 and archive)
- 3 medium monoliths (TCLP and archive)
- 5 large monoliths (chemical analysis, physical/engineering tests and archive).

An EPA sample tag with a unique number was affixed to each container or mold; these numbers served as the sample numbers. Each sample shipped for analysis at this time also had a unique Organic Traffic Report (OTR) or Inorganic Traffic Report (ITR) number and was listed on an Analysis Request Form. As the samples were created, a master set of chain-of-custody forms was filled out. Those forms cross-referenced material type with sample number and ITR or OTR number. Each batch of samples shipped at this time was accompanied by its own chain-of-custody form.

Data received from the analytical labs referenced results by sample (tag) number or by ITR or OTR number. The physical-testing laboratory referenced the samples by their original sample numbers. In each case, the materials tested were readily ascertained by checking the master custody forms. The TCLP extractions created two leachates per sample (one for volatiles, one for all other analytes). The laboratory identified these by the original sample number of the solid material extracted. Each ANS test created seven leachates per monolith. Each was given a tag with a unique number as it was collected, and analytical results were referenced to this number. A special form, kept by the laboratory performing the ANS leaching, was used to document these sample numbers and cross-reference them to the sample number of the monolith being tested. Appendix A shows a copy of this form and each of the other forms used to track samples.

RESULTS AND CONCLUSIONS

Characteristics of On-site Materials

At each of the locations where auto fluff was collected, it was spread on a plastic sheet, photographed, and described. One-third of the fluff (by volume) passed the 3/8-inch screen. This fine fraction consisted almost entirely of decaying foam derived from auto upholstery. The large size fraction included debris of various kinds: large chunks of foam, rubber, plastic, building rubble, and rock. The moisture content of the minus-3/8-inch fraction was 29 percent. Its wet bulk density was 50 pounds per cubic foot (pcf); the dry bulk density was 35 pcf. Simon & Sons (AGI, 1987) reported a dry bulk density for fresh auto fluff of 20 pcf. The higher value found in this study confirms that fluff left atop the ground for several years is considerably broken down.

The site soil was very coarse; about 40 percent was larger than 3/8 inch. The moisture content of the fine fraction was 19 percent. Soil bulk density was not measured.

The project protocol (MDI, 1988) sets forth an optional procedure for field classification of on-site debris according to size and composition. This information will be needed for pilot testing and full-scale fixation. It was not necessary for the bench fixation and, since it is cumbersome and time consuming, it was not performed for this project.

Chemical Concentrations

Appendix B contains a full set of chemical concentration data for both solid materials and leachates. Applicable detection limits and values for the sand blank are found therein. The text discusses an abbreviated list of contaminants, focusing on those for which site cleanup standards have been established.

Contaminant concentrations in the raw materials are shown in Table 3. Auto fluff alone was not characterized, but comparison of the soil data with the mixed soil:fluff results gives an indication of concentrations in the fluff. Both soil and fluff contained 2000-3000 mg/kg lead. Phenols, derived from tar, were apparently more concentrated in soil and fluff (>300 mg/kg) than in raw tar (200 mg/kg). The BTX compounds were found at very low levels (<10 μg/kg) in the soil and fluff; analytical problems invalidated the volatiles results for tar.

Among the PAHs, pyrene was found in the highest concentration in the soil and fluff and is therefore, a sensitive indicator of tar contamination. Pyrene was found at low but measurable levels (<10 mg/kg) in soil and fluff. The six PAHs on which site cleanup standards are based were found at very low concentrations in soil (0.9-3.4 mg/kg) and lower concentrations in fluff (<0.2-2.5 mg/kg).

The PCBs were found in both auto fluff and soil; their total concentration was apparently more than five times greater in fluff than in soil (33 vs 6.2 mg/kg, calculated from results for the soil and the 3:1 mix). Among all the materials collected on site, Aroclors 1016, 1221, 1232, and 1248 were generally below detection (at 5-10 mg/kg), while Aroclors 1242, 1254, and 1260 could be estimated.

Table 4 summarizes RI contaminant data for surficial materials on the site. Values for most parameters ranged very widely. In general, it appears that the materials collected for the fixation study were representative of those found during the Remedial Investigation. Previously reported lead and PCB levels ranged over two orders of magnitude. Results from the fixation

Table 3. Summary of Chemical Concentrations in Raw Materials

Contaminant or Contaminant Class[a]	Concentration (mg/kg) Soil	Tar	1:1 Soil:Fluff	3:1 Soil:Fluff[b]
Arsenic	137	-	61.9	141 ± 14
Lead	2490J	-	3080	2120 ± 134J
Total Phenols	377	201	584	389 ± 66
Benzene	0.002J	R	0.007UJ	0.007UJ
Toluene	0.008J	R	0.007UJ	0.007UJ
Xylenes	0.008J	R	0.007UJ	0.007UJ
Pyrene	8.3J	3,200J	4.2J	7.4 ± 4.1J
Benzo(a)anthracene	3.4J	1,200J	1.8UJ	1.7UJ
Benzo(b)fluoranthene	2.6J	350J	2.5J	2.8 ± 1.4J
Benzo(k)fluoranthene	2.3J	510J	1.8UJ	1.8 ± 0.61J
Benzo(a)pyrene	3.0J	740J	1.4J	2.6 ± 1.1J
Indeno(1,2,3-cd)pyrene	1.3J	240J	1.1J	1.4 ± 0.47J
Dibenz(a,h)anthracene	0.9J	200J	0.56J	0.84± 0.18J
Total PCBs[c]	6.2J	198U	32.4J	13 ± 2.1J

a. For a full listing of contaminants analyzed, see Appendix B.

b. Results from analysis of triplicate samples, plus/minus the standard deviation. Below-detection values are incorporated as the detection limit.

c. Sum of Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260. Below-detection values excluded.

Note: J = approximate value; U = undetected at this level; R = data unusable; UJ = undetected at approximately this level.

Table 4. Chemical Concentrations Reported from the RI

Contaminant or Contaminant Class	Concentration Range (mg/kg)[a] (Number of Samples) Shallow Soil	 Tar from Tar Pit	 Auto Fluff
Arsenic	28-70 (2)	<2.0 (1)	<0.5 - 363(6)
Lead	73-12,900(10)	37 (1)	2910-4700 (7)
Phenols	<1 (1)[b]	150 (1)	
Benzene	<0.001 (1)	430 (1)	
Toluene	<0.001 (1)	200-950(2)	
Xylenes	<0.001 (1)	350-1700(2)	
Pyrene	1.8 - <9.5 (3)	1650-4000(2)	
Benzo(a)anthracene	0.4 - <39 (3)	<25 -1300(2)	
Benzo(b)fluoranthene	0.2- < 12.5(3)	275 (1)	
Benzo(k)fluoranthene	0.24- < 12.5(3)	750-770(2)	
Benzo(a)pyrene	0.29- < 12.5(3)	660-900(2)	
Indeno(1,2,3-cd)pyrene	<0.37- < 18.5(2)	90(1)	
Dibenz(a,h)anthracene	<0.25- 2.3(3)	890(1)	
Total PCBs[c]	<0.7-135(15)		11 - 204(8)

a. PAH values are dry weight; all others wet weight basis.

b. 2,4-dimethylphenol only

c. Sum of seven Aroclors, below-detection values excluded

Reference: AGI (1987)

studies fall within these ranges (note that the RI values are on a wet-weight basis; corresponding dry-weight values may be up to 35% higher). PAH levels in soil also fall within the previously reported ranges.

The contaminant concentrations found in cylinders of fixed material are summarized in Table 5. Note that all of the results for the indicator contaminants have been qualified as "approximate values," either because of low concentrations relative to the detection limit or because of QA/QC outliers identified during data validation. Volatile compounds were not analyzed in fixed materials. A separate analysis for total phenols was not done, and the reported value is the sum of 12 individual assays from the B/N/A scan. This sum is only roughly comparable to the result of the colorimetric "total phenols" test, which is sensitive to many more phenolic compounds.

Mixing with the fixation reagents should change the contaminant levels. Concentrations of organics should diminish simply because of dilution; levels of some metals might be enhanced by the fixation reagents. Comparison of the raw and fixed materials (Tables 3 and 5) indicates that lead concentrations declined somewhat, reflecting dilution. Arsenic levels apparently increased in some materials and decreased in others. Assuming the fixaton reagents were well-mixed, this could not happen, so the arsenic results for the fixed materials should probably be discounted. Reported PAH and PCB levels were generally similar in the raw and fixed samples of each material. In the soil sample, reported levels of organic compounds increased slightly consequent to fixation. These low values must clearly be treated as estimates.

If considered as "soils," the fixed materials would not, themselves, meet cleanup criteria established for the Tar Pits site (see Table 1). The soil lead standard of 166 mg/kg and the PCB standard of 1 mg/kg would be exceeded. Most stabilized mixes of site materials would probably also exceed the PAH cleanup goal of 1 mg/kg.

Physical Properties

Selected physical properties of the fixed materials are listed in Table 6. For fixed site samples, bulk density ranged from 82 pounds per cubic foot (pcf) (for fixed tar) to 110 pcf (soil). Moisture contents, as determined from drying of whole cylinders at 60°C, ranged from 13.3 percent for soil to 20.7 percent for tar. The correspondence of these "apparent moisture content" data to results obtained from drying of crushed samples at 103-105°C is not well established, but is thought to underestimate moisture content by no more than two percent for the soil and soil-fluff cylinders (Center Hill, 1989). Enough volatile compounds were present in the tar and tar-soil cylinders that their moisture contents may have been slightly overestimated by this procedure.

Based on the bulk densities of raw and fixed materials, the volume change on fixation can be calculated. For the proportions of sample, water, and reagents used in these tests, the approximate volume increases were:

soil	95%
1:1 soil:fluff	49%
3:1 soil:fluff	75%
tar	45%
1:1 soil:tar	62%,

i.e., one cubic foot of field-moist soil (at 130 pcf) fixed according to this protocol yields 1.95 cubic feet of final product. This assumes the fixed mixture neither shrinks nor swells during

Table 5. Chemical concentrations in fixed materials

Contaminant or Contaminant Class	Concentration (mg/kg)				
	Soil	Tar	1:1 Soil:Tar	1:1 Soil:Fluff	3:1 Soil:Fluff[a]
Arsenic	354 J	2.8 J	27.5 J	58 J	55.8 ± 1.1 J
Lead	877 J	52.3 J	410 J	2770 J	1790 ± 330 J
Total Phenols	1450 U	1050 U	5,050 U	1970 U	1900 U
Pyrene	17 J	2,600 J	1,100 J	14 J	13.2 ± 3.3 J
Benzo(a)anthracene	7.2 J	810 J	490 J	58 UJ	56 U
Benzo(b)fluoranthene	51 UJ	870 J	350 J	58 UJ	56 U
Benzo(k)fluoranthene	51 UJ	b	b	58 UJ	56 U
Benzo(a)pyrene	6 J	800 J	290 J	58 UJ	4.2 ± 0.42 J
Indeno(1,2,3-cd)pyrene	51 UJ	330 J	90 J	58 UJ	56 U
Dibenz(a,h)anthracene	51 UJ	140 J	47 J	58 UJ	56 U
Total PCBs	6.6 J[c]	28 UJ	67 U	16.2 J[c]	8.8 ± 2.1 J

a. Results from analysis of three cylinders, plus/minus the standard deviation. Below detection values incorporated as the detection limit.

b. Sum of benzo(b)fluoranthene and benzo(k)fluoranthene shown under benzo(b) fluoranthene

c. Sum of seven Aroclors, excluding below-detection values.

Note: J = approximate value; U = undetected at this level.

Table 6. Physical Properties of Fixed Materials

		Mean Value, Standard Deviation, Number of Replicates		
Fixed Material	Wet Bulk Density(pcf)	Apparent Moisture Content(%)[a]	Calculated Dry Density(pcf)	Wet/Dry Weight Loss(%)
Soil	110 ± 1 3	13.3 1	97.1	3.0 ± 1.0 2
1:1 Soil:Fluff	101 ± 1 3	17.0 ± 3.7 2	86.3	2.8 ± 0.6 2
3:1 Soil:Fluff	105 ± 3 9	16.3 ± 3.2 6	90.3	1.7 ± 2.1 6
Tar	82 ± 0.9 3	20.7 1	67.9	6.4 ± 7.6 2
1:1 Soil:Tar	92.5 ± 1.6 3	18.6 1	78.0	5.1 ± 5.8 2
Sand Blank	120 1	8.5 1	110	3.7 1

a. Apparent moisture content determined by drying whole cylinders at 60°C.

curing, and no weight is lost. Since soil makes up the great preponderance of material to be fixed at the Tar Pits, the final monolith might have nearly twice the volume of contaminated material fixed. If smaller amounts of reagents and water were used, there would be less of a volume increase. In the vendor's experience fixing metal-contaminated soils using an optimum Mix-of-Record, observed volume increases have been about 10 percent (Larsen, 1989).

The principal measure of durability associated with wet/dry stressing is weight change; the less weight lost by a cylinder of fixed material, the more durable the material is considered. Fixed Tar Pits samples showed weight losses ranging from -0.9 percent (water weight was actually gained during the test) to 12 percent. There is no standard for performance in the wet/dry durability test, but weight loss of five percent or less is generally judged acceptable (Cullinane *et al.*, 1986). In these tests, weight losses exceeding five percent were shown by tar and tar-soil cylinders (11.8 and 9.2 percent, respectively). Soil and soil-fluff cylinders averaged a three percent weight loss, or less.

Cylinders of 3:1 soil:fluff were tested to trace the development of compressive strength during curing. Most concrete formulations cure relatively quickly, and the 28-day compressive strength is known as the "ultimate strength" (although strength continues to increase very slowly for many years). The development of strength in the soil:fluff mixture is shown in Figure 4. These cylinders achieved 85 percent of their ultimate strength in 21 days, and the time trend suggests they were still gaining measurable strength at day 29. An average 29-day strength of 690 psi was attained by the cylinders. In these mixtures the presence of foam and free organic compounds may slow the development of strength. A 50-day test may be a better measure of ultimate strength than the standard 28-day concrete test.

Ultimate (29-day) compressive strengths of the various types of fixed materials are shown in Figure 5. The mixes with higher proportions of soil developed greater strength; both auto fluff and tar detracted from monolith strength. A slight effect of water content may be reflected in these results. The ultimate strength of concrete is inversely related to the water content of the formulation. In these tests, the soil formulation contained 11 percent less water than the 1:1 soil:fluff mix and six percent less than the 3:1 mix. However, the tar formulations contained considerably less water than the soil mix, but were nonetheless much weaker. Among unstressed cylinders, fixed soil had the greatest strength (895 psi) while fixed tar had the least (0). There are no general standards for unconfined compressive strength of soils fixed during site remediation. The Nuclear Regulatory Commission requires that rigid waste materials exhibit a strength of 150 psi or greater. Fifty psi is the proposed minimum strength for land-disposed RCRA solid wastes. A three-foot-thick monolith of fixed Tar Pits soil would only exert an overburden pressure of 2 psi, so these results indicate the fixed materials (other than tar) would not collapse or fracture under their own weight, and could probably meet a site-specific strength standard.

For every material type, wet/dry-stressed cylinders were stronger than unstressed cylinders. This is probably attributable to temperature differences: during the "dry" portions of the stress tests, the cylinders were held at 60°C. This undoubtedly accelerated their curing substantially. Because of this, effects due solely to cyclic wetting and drying cannot be distinguished.

The permeabilities of the fixed materials are depicted in figure 6. The experience of the testing laboratory indicates these values should be regarded as accurate to about one-quarter of an order of magnitude (Center Hill, 1989); additionally, coefficients of variation for triplicate 3:1 soil:fluff samples were 42 percent and 12 percent for unstressed and stressed cylinders, respectively. The most permeable cylinder tested was fixed 1:1 soil:tar that had been wet/dry

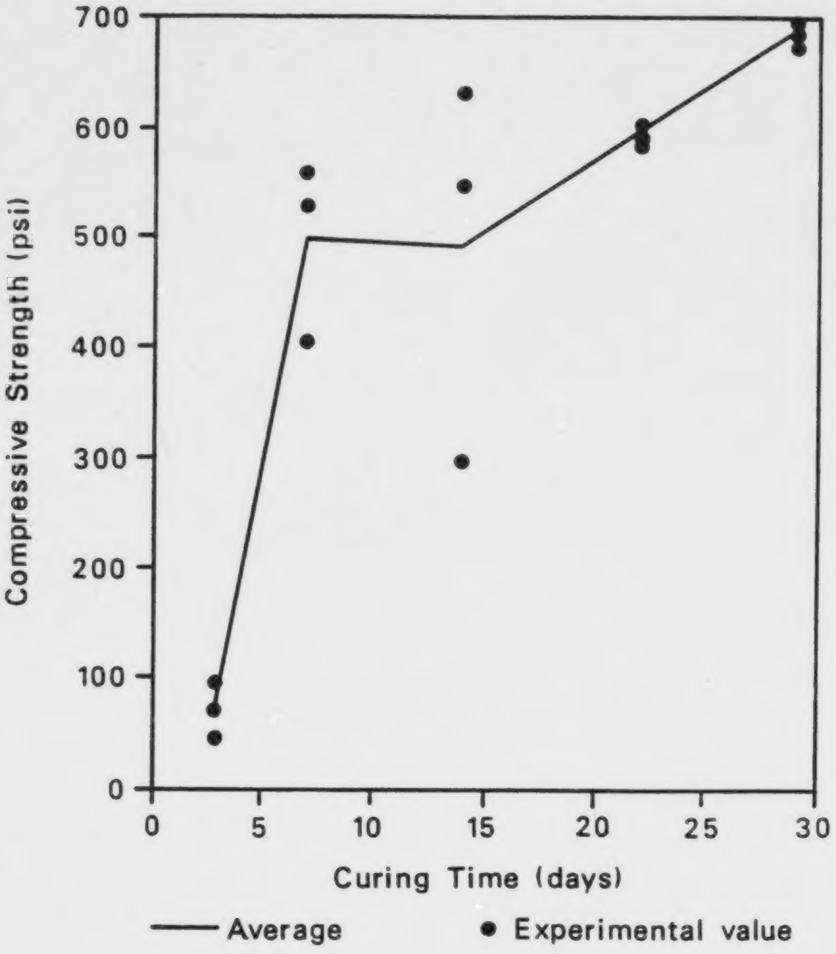


Figure 4. Development of compressive strength in a fixed 3:1 soil:auto fluff mix.

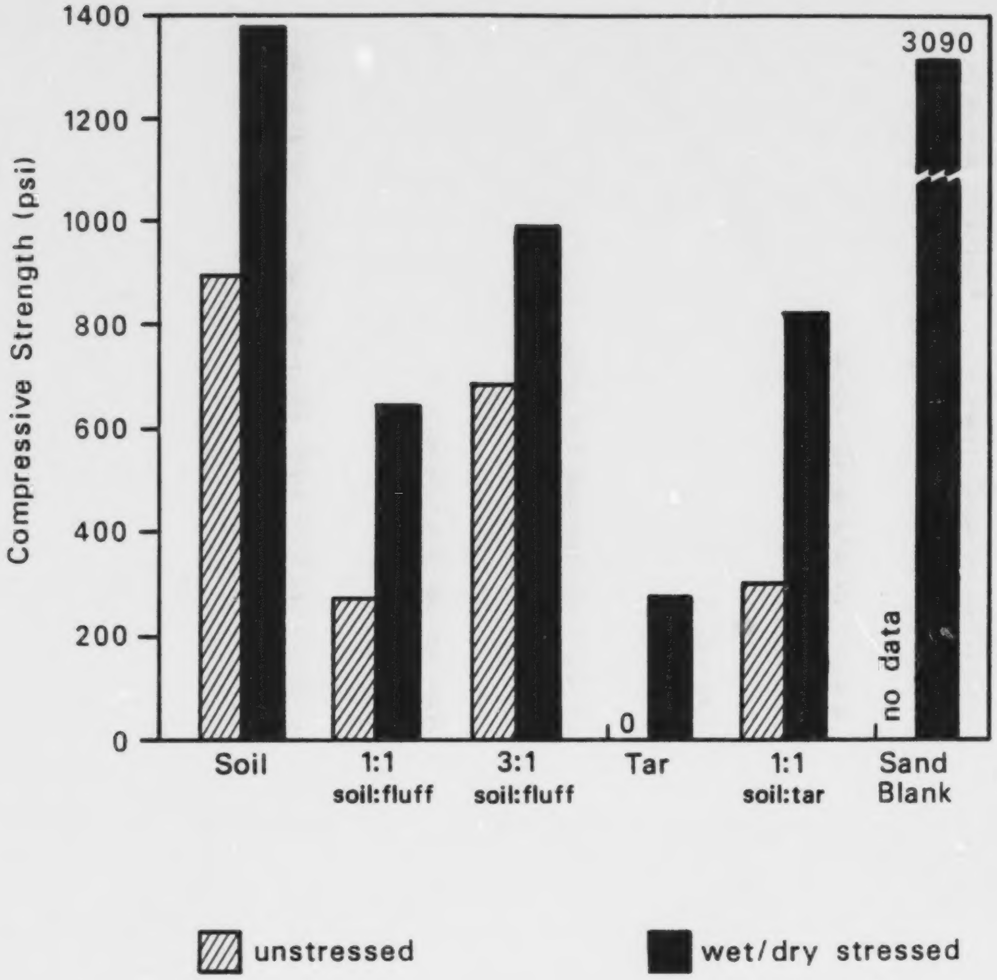


Figure 5. Unconfined compressive strengths of fixed materials. Results for 3:1 soil:fluff mixture are means of triplicates; all others are single determinations.

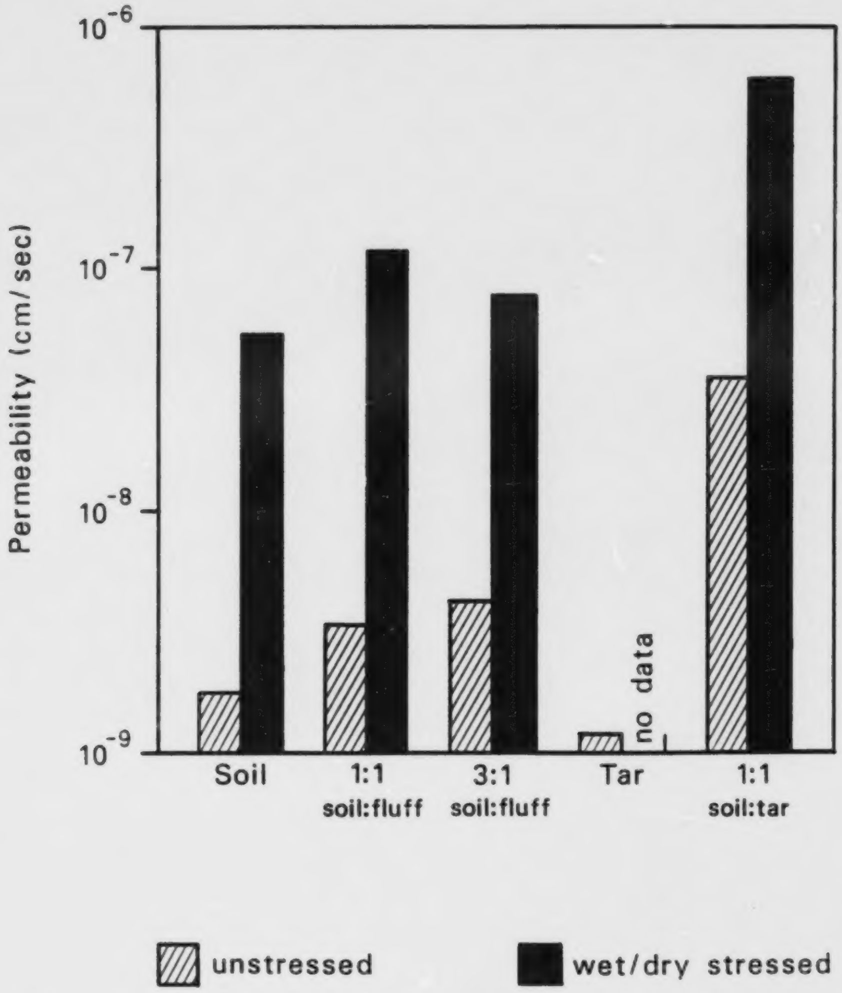


Figure 6. Permeabilities of fixed materials. Results for 3:1 soil:fluff mixture are means of triplicates; all others are single determinations.

stressed; its permeability was 6 x 10^{-7} cm/sec. The least permeable material, unstressed tar had a permeability (or saturated hydraulic conductivity) of 1.2 x 10^{-9} cm/sec. Unstressed fixed soil, 1:1 soil:fluff and 3:1 soil:fluff all had permeabilities within a factor of three. It appears that the inclusion of auto fluff with soil altered the monolith permeability little, if at all. The tar cylinder that was to be permeability-tested after wet/dry stressing developed cracks during the stressing, rendering it infinitely permeable (and untestable).

Permeability criteria for site cleanups are developed on a site-specific basis, according to site hydrologic conditions. Thus, there are no general standards for the hydraulic conductivity of fixed materials. A soil having a permeability of 10^{-6} cm/sec or lower would generally be considered highly impermeable (permeabilities of natural clays are in the range 10^{-7}-10^{-5} cm/sec).

For each type of fixed material, permeability was greatly increased by wet/dry stressing. The increases ranged from a factor of 17 (for 1:1 soil:tar) to a factor of 30 (for 1:1 soil:fluff). The unstressed cylinders were tested first, and hence cured for a shorter period before permeability testing. It is possible that some of the observed permeability differences were related to cylinder age. Alternatively, the cyclic wetting and drying may have opened microscopic pores near the cylinder surface, by dissolution or other mechanisms. The ANS leaching results (see following section) indicate that such dissolution did occur. Increased permeability through dissolution, plus the failure of the tar cylinder during stressing, suggest that the integrity of an in-place monolith would be greatly enhanced by keeping it dry.

Leaching Properties

Table 7 is a synopsis of results from the TCLP leaching of raw materials. Results for the complete suite of analytes are tabulated in Appendix B. High levels of lead leached from soil-containing samples (>10 mg/L). More than 5 mg/L total phenols and 0.5 mg/L of volatile compounds were extracted from the raw tar. The PAHs of interest were generally undetectable (at very low levels) in all of the leachates. Total PCB concentrations were below 0.2 μg/L.

For those parameters that were quantified in the solid raw samples, the proportion extracted by the TCLP can be calculated. This is based on the solid-phase and leachate concentrations and the liquid-solid ratio in the TCLP (20:1 weight ratio). In these TCLP tests, 8-42 percent of the lead in the raw samples was leached into the liquid. Fifty-two percent of the phenols in the raw tar were leached. The proportions of PAHs extracted were low, generally less than three percent. As might be predicted from their solubility, only a tiny fraction of the PCBs leached into the liquid ($2x10^{-4}$).

To aid in interpreting TCLP results, "regulatory levels" have been proposed by EPA for a number of contaminants as quantified in TCLP leachates. Those applicable to the Tar Pits data are listed in Table 8. Leachates from the raw materials were beneath the proposed upper levels for arsenic, phenols, and toluene. Leachates from soil-containing material exceed the proposed lead standard, and the benzene standard was exceeded by the tar extract. There are no TCLP regulatory levels for PAHs or PCBs.

Table 7. Chemical concentrations in TCLP leachates from raw materials

Contaminant or Contaminant Class	Concentration (μg/L) Soil	Tar	1:1 Soil:Fluff	3:1 Soil:Fluff[a]
Arsenic	164 J	1 U	131 J	138 ± 50 J
Lead	51,000	165	12,520	44,290 ± 26,190
Phenols	135 U	5250	139 U	161 U
Benzene	5 UJ	200 J	5 UJ	5 UJ
Toluene	3 J	330 J	0.9 J	0.6 ± 0.3 J
Xylenes	5 UJ	94 J	5 UJ	5 UJ
Pyrene	4 U	26 U	4 U	0.2 ± 0.1 J
Benzo(a)anthracene	4 U	26 U	4 U	4 U
Benzo(b)fluoranthene	4 U	3 J	4 U	4 U
Benzo(k)fluoranthene	4 U	26 U	4 U	4 U
Benzo(a)pyrene	4 U	26 U	4 U	4 U
Indeno(1,2,3-cd)pyrene	4 U	26 U	4 U	4 U
Dibenz(a,h)anthracene	4 U	26 U	4 U	4 U
Total PCBs[b]	0.06	2.1U	0.35U	0.12 ± 0.05

[a] Results from analysis of triplicate samples, plus/minus the standard deviation. Below-detection values are incorporated as the detection limit.

[b] Sum of Aroclors 1016, 1221, 1242, 1248, 1254, and 1260. Below-detection values excluded.

Note: J = approximate value; U = undetected at this level; UJ = undetected at approximately this level.

Table 8. Proposed Standards for TCLP leachates

Parameter[a]	Proposed Regulatory Level mg/L
Arsenic	5.0
Lead	5.0
Phenol	14.4
Chlorinated phenols[b]	11.7
Benzene	0.07
Toluene	14.4

a. Partial list of regulated compounds; those of concern at the Tacoma Tar pits.

b. Includes penta, 2,3,4,6-tetrachlorophenol, 2,4,5-trichlorophenol and 2,4,6-trichlorophenol.

Reference: Federal Register, vol.51 no. 114, Friday, June 13, 1986, pp. 21647-21684.

The TCLP leachates of raw materials exceeded the cleanup standards for surface and groundwater on the site (see Table 1). Leachate concentrations of PAHs and PCBs were well within the cleanup goals, but the tar extract exceeded the benzene standards, and the soil leachates exceeded the lead standards by two orders of magnitude or more. It should be noted that the version of the TCLP used for these samples is a fairly severe procedure, having an initial pH of 2.9, whereas pH values for site surface and groundwater range from 6 to 7.5 (AGI 1987). In addition, the samples were finely ground prior to the extractions.

Table 9 summarizes results of the TCLP leaching of fixed materials. Volatile compounds were extracted and analyzed in the tar and tar-soil cylinders only. PCBs were not measured in these leachates. The results indicate that fixation was very effective in immobilizing lead. The highest proportion of lead that leached from any crushed fixed material was 4×10^{-4}. The leaching of phenols was also decreased beyond the effect of simple dilution (the fixed cylinders were about 60% raw material and 40% additives). Fixation did not inhibit the leaching of volatile compounds from the cylinders in which they were very concentrated; the BTX compounds leached from tar-containing cylinders at 72 mg/L. PAHs were extracted at extremely low levels. In the two cases where they could be quantified, the proportions of PAHs leached were 10^{-4} or less. Because of the many below-detection results, PAH leaching rates cannot be compared between the raw and fixed materials.

Leachates from the fixed samples fell within proposed TCLP regulatory guidelines in almost all respects (see Table 8). The sole exception was the leachate from fixed tar, which contained more than 500 μg/L benzene. The proposed regulatory level for benzene is 70 μg/L.

Compared to the site cleanup goals (Table 1), these TCLP leachates were similar to those from raw materials. They would probably meet the PAH and PCB standards for site waters. Leachates from tarry wastes contained excessive benzene, relative to the standards. Although the leaching of lead was considerably inhibited by fixation, pure TCLP leachates would exceed the lead standard for surface waters at the site boundary.

In the ANS tests, fixed cylinders were leached in seven successive batches of deionized water over a period of 90 days. Figure 7 shows leachate pH data from these tests. Figure 8 shows leachate electrical conductivity (EC), a measure of dissolved salts. All of the fixed materials (including the sand blank) exhibited the same behavior: an initial release of alkalinity into the leaching solution (as indicated by high pH and EC) which diminished after about four weeks. These results indicate an early "washout" of alkaline oxides and hydroxides from the surface layers of the fixed cylinders. These compounds were derived principally from the cementitious fixation reagents, hence pH and EC trends for the fixed tar paralleled those for the soil mixes, which contained much more natural alkalinity. The pH and EC trends suggest leaching of soluble compounds was controlled by two phenomena. Initially, portions of the surficial materials dissolved fairly readily and leached into solution. Towards the end of the experiments, soluble surface materials were mostly gone, and leaching was limited by the low rate of diffusion through the solid cylinders.

Contaminant concentrations in the ANS leachates were generally very low. Among the metals analyzed, only copper and zinc were consistently detectable; their concentrations in most leachates were below 30 μg/L, but ranged up to 78 μg/L. Lead was never detected (at 50 μg/L). In the leachates from fixed soil and soil:fluff mixes, PAHs were generally below detection. Those compounds that were quantified (phenanthrene, anthracene, benzo(b) fluoranthene, and benzo(k)fluoranthene) were present at levels of 100 ng/L or less. PAHs did leach from the tar and tar:soil cylinders. Leachate concentrations of selected PAHs are shown

Table 9. Chemical concentrations in TCLP leachates from fixed materials.

Contaminant or Contaminant Class	Concentration ($\mu g/l$) Soil	Tar	1:1 Soil:Tar	1:1 Soil:Fluff	3:1 Soil:Fluff[a]
Arsenic	2	2	4	8	6.3 ± 0.6
Lead	17	1 U	1 U	23	11 ± 8.7
Phenols[b]	418 U	420	1180	23	15 ± 4 J
Benzene	-	537	59	-	-
Toluene	-	1000	540	-	-
Xylenes	-	674	505	-	-
Pyrene	12 U	4 J	5 J	13 U	62 U
Benzo(a)anthracene	12 U	12 U	12 U	13 U	62 U
Benzo(b)fluoranthene	12 U	12 U	12 U	13 U	62 U
Benzo(k)fluoranthene	12 U	12 U	12 U	13 U	62 U
Benzo(a)pyrene	12 U	12 U	12 U	13 U	62 U
Indeno(1,2,3-cd)pyrene	12 U	12 U	12 U	13 U	62 U
Dibenz(a,h)anthracene	12 U	12 U	12 U	13 U	62 U

a. Results from analysis of triplicate samples, plus/minus the standard deviation. Below-detection values incorporated as the detection limit.

b. Sum of individual compounds quantified in the B/N/A scan. Below-detection values excluded.

Note: J = approximate value; U = undetected at this level.

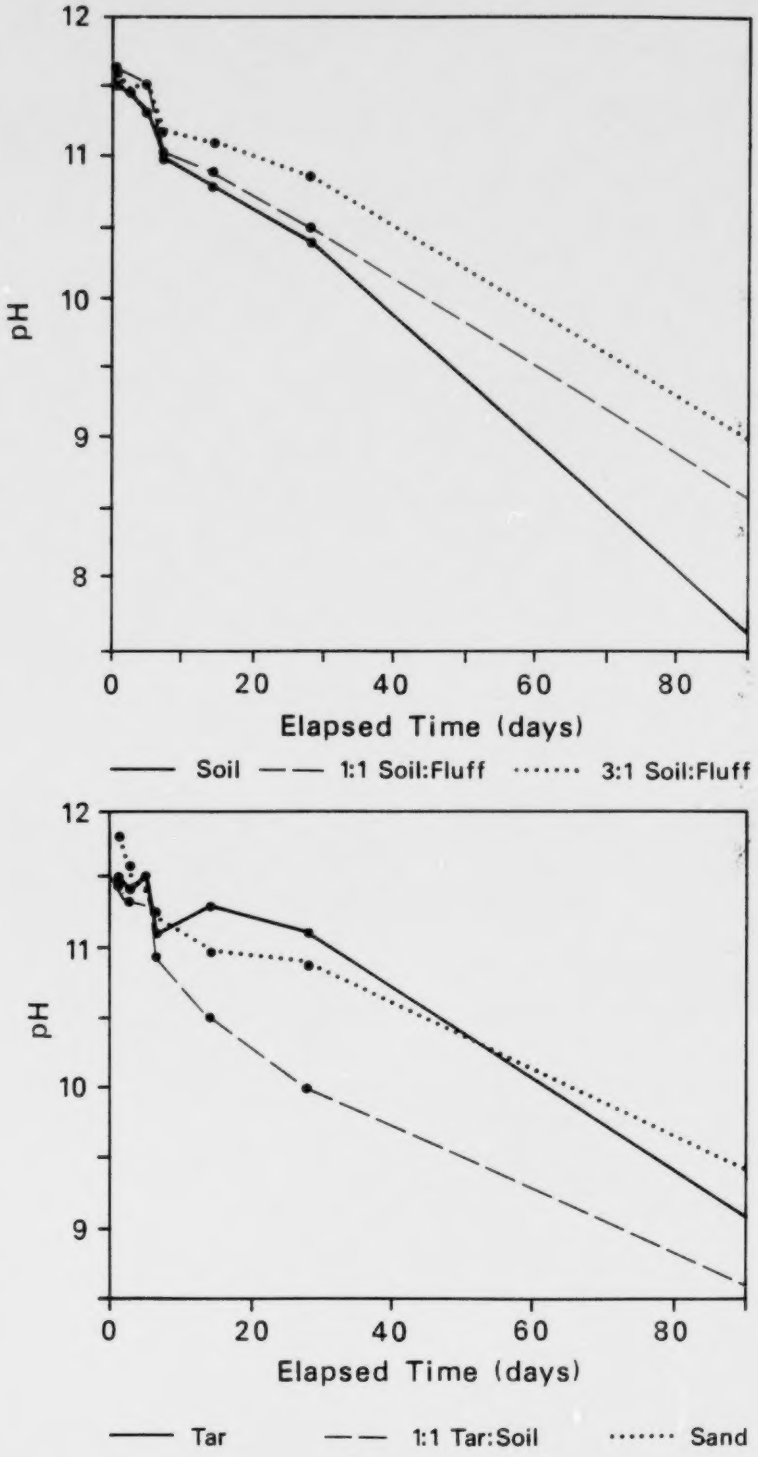


Figure 7. ANS leachate pH vs. time.

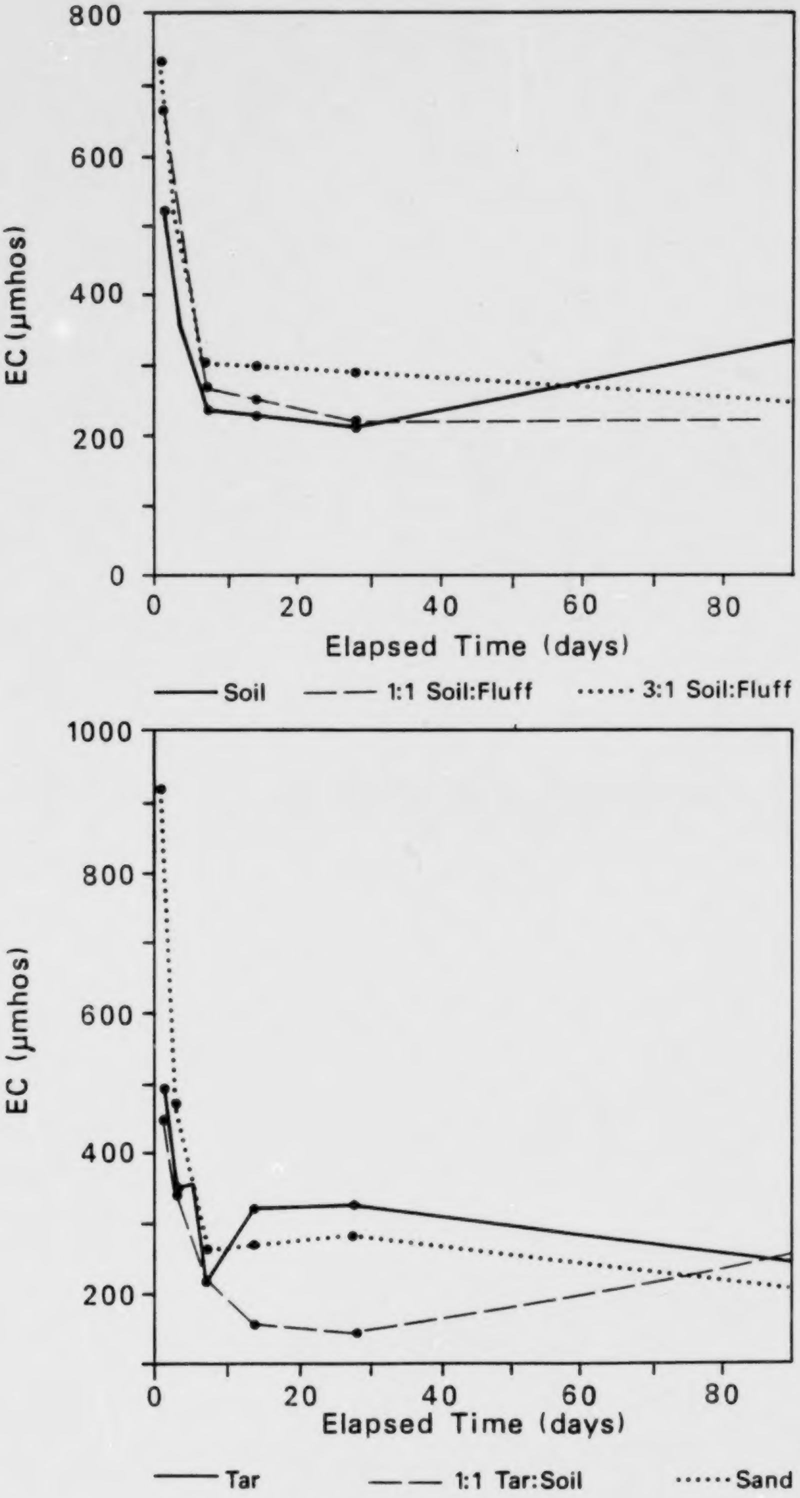


Figure 8. ANS leachate conductivity vs. time.

in Table 10. Of these compounds naphthalene, fluorene, and pyrene were present at high levels in the raw tar. Benzo(a)anthracene and benzo(a)pyrene were low-level constituents of tar, but are named in the site cleanup goals. PAH levels in the leachates roughly reflected those in the tar itself. Compounds with fewer rings were released more readily than those with more rings. The raw tar contained one-fifth as much pyrene as naphthalene, but less than one one-hundreth as much was found in the ANS leachates.

Detection levels for PCBs in the ANS leachates ranged from 0.1 to 0.3 µg/L. No PCB was detected in any leachate from these tests.

Phenols leached from all of the cylinders in measurable quantities. Leachate phenol levels are shown as a function of time in Figure 9. Leachates from tar-containing cylinders averaged 300 µg/L in total phenols, while leachates from the fixed soil and soil:fluff mixes contained 5 - 50 µg/L. In all of the experiments, there was a drop in the leachate phenol concentrations after 1 - 2 weeks, then a rise toward the end of the leaching period.

Because of the unequal leaching intervals in the ANS tests, leaching rates cannot be inferred directly from concentration-versus-time data. The duration of each interval and the total elapsed time are taken into account by deriving the "leachability index" of a compound of interest (ANS 1986). For each compound, for each leachate, a diffusivity (in cm^2/sec) is calculated. This is based on the incremental leaching time, the cumulative leaching time, the geometry of the cylinder, and the fraction of the compound initially present in the cylinder that was released into that leachate. The leachability index L is the inverse logarithm of the diffusivity. It is calculated for each leachate and averaged over the entire test (seven leachates, in this case); changes in L with time are also meaningful. Higher L values correspond to slower release of the contaminant into the leachates. An L value of 5 would indicate a fairly mobile compound (diffusivity = 10^{-5} cm^2/sec) while a value of 15 would indicate an essentially immobile compound (diffusivity = 10^{-15} cm^2/sec).

Table 11 shows leachability indices for selected contaminants in fixed cylinders of Tar Pits materials. In cases where the initial solid-phase concentration in the cylinder was known but leachate concentrations were below detection, a "greater-than" value representing a minimum leaching index was calculated. For most of the contaminants of interest in the Tar Pits study, calculated leachability was greater than 10, indicating these contaminants were relatively immobile in the fixed material. Furthermore, for most organic and inorganic contaminants there was no time trend in leaching rate, as expressed by the seven L values. The sole exception was total phenols. In tests of all types of fixed cylinders, the index value for phenols increased uniformly over time, indicating diminishing mobility with time. Increases in L value ranged from 0.5 to 1.6.

The leachability index is inversely related to the fractional proportion of contaminant leached. During these 90-day experiments about 14 percent of the phenols originally present in the tar and tar:soil cylinders were extracted. For other constituents in these and other cylinders, the proportion extracted was three percent or less. Among the PAHs greater proportions of the lighter compounds were leached (2.5 - 3% for naphthalene in tar-containing cylinders), while very small fractions of the heavier PAHs leached (.02% of benzo(a)pyrene, for example). Presumably, both light and heavy PAHs are affected equally by physical entrapment, but the lighter PAHs are both more soluble and less likely to be held within the cylinders by adsorption. Almost all of the leachate PAH concentrations were below published solubility limits (Mills *et al*, 1982); most were an order of magnitude below the limits. It appears that adsorption, acting particularly strongly on the heavier compounds, may be important in immobilizing PAHs under these leaching conditions.

Table 10. Concentration of selected PAHs in ANS extracts of fixed tar samples

	Concentration (μg/L)				
Elapsed Time (days)	Naphthalene	Fluorene	Pyrene	Benzo(a) anthracene	Benzo(a) pyrene
			Fixed Tar		
1	2,000	80	20 U	3 U	3 U
3	2,000	100	20 U	3.2U	3.2U
5	2,000 J	100 J	20 UJ	4 UJ	4 UJ
7	1,000	100	20 U	0.08 U	0.08 U
14	600	100	60 U	0.2 U	0.2 U
28	10,000	900	60 U	0.2 U	0.2 U
90	700	80	30 U	7	5
			Fixed 1:1 Tar:Soil		
1	2,000	80	20 U	3 U	3 U
3	2,000	100	20 U	3 U	3 U
5	4,000 J	700 J	20 UJ	4 UJ	0.25 J
7	1,000	100	20 U	3 U	0.20
14	500	70	50 U	0.2 U	0.2 U
28	2,000	300	30 U	0.2 U	0.2 U
90	400	70	25 U	4.1 U	4.1 U

Note: J = approximate value, U = undetected at this level, UJ = undetected at approximately this level.

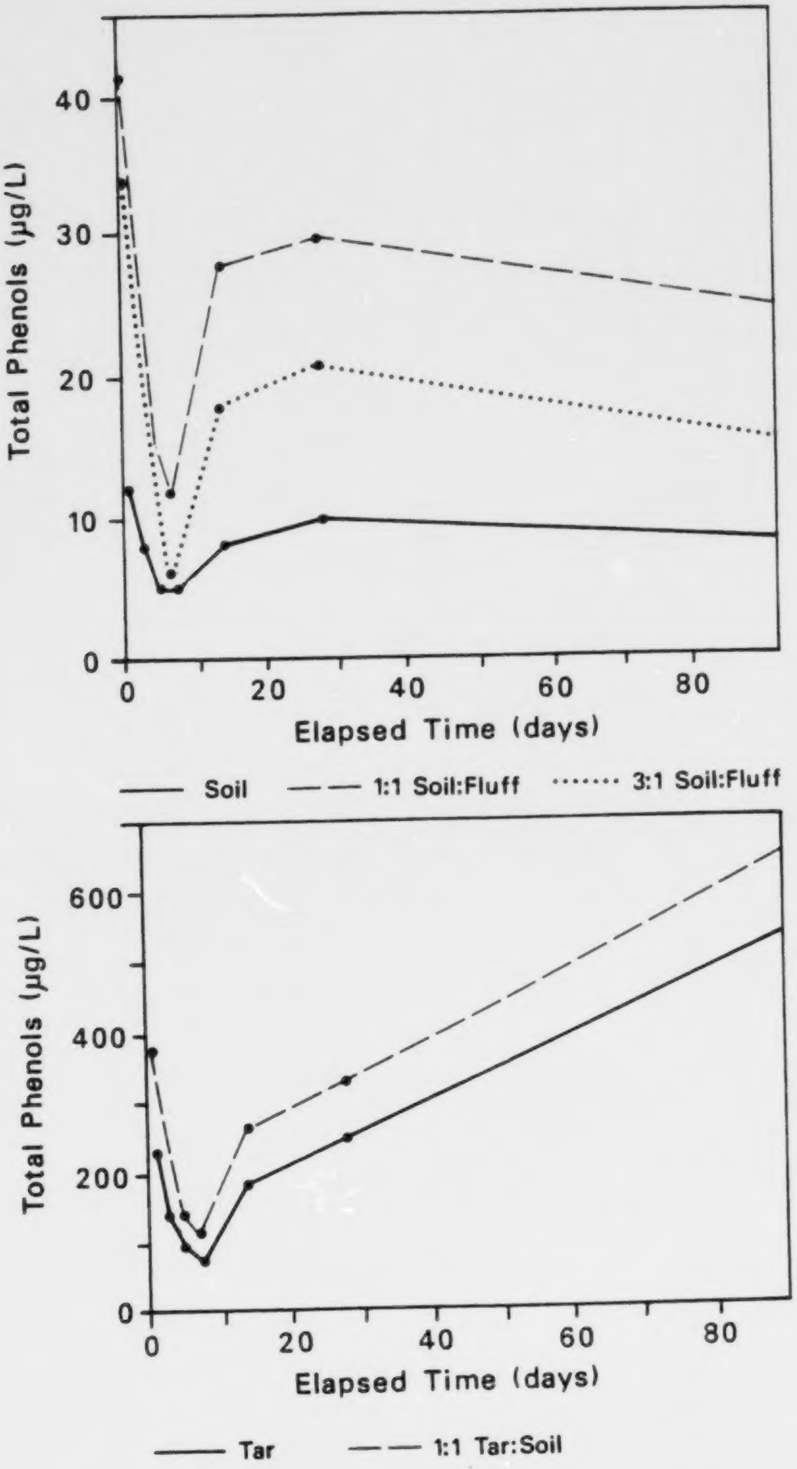


Figure 9. ANS leachate phenols vs. time.

Table 11. Leachability Indices for Unstressed Fixed Materials

	Average Leachability Index[a]			
Parameter	Soil	Tar	1:1 Soil:Tar	1:1 Soil:Fluff
Arsenic	> 13.6	-	-	12.2
Copper	-	-	-	14.6
Lead	> 12.2	-	-	> 13.2
Phenols[b]	12.4	8.9	8.9	11.7
Naphthalene	>9.2	10.9	10.3	-
Pyrene	> 12.5	> 13.2	> 12.7	> 12.2
Benzo(a)pyrene	> 13.1	> 15.2	> 14.7	-
PCBs[b]	> 12.1	-	-	> 13.4

a. Average of seven intervals.

b. Initial concentrations in the fixed cylinders not quantified; assumed to be half those in the constituent raw materials.

The leachability index can be used to estimate the cumulative contaminant leached from a fixed monolith at specific times in the future (ANS, 1986). The calculation is:

$$F = 1.128(10^{-0.5L})(t_n)^{0.5}(S/V)$$

where F = fraction of total contaminant leached
L = average leachability index
t_n = total time of leaching
S = monolith surface area
V = monolith volume

For selected Tar Pits materials, estimates for 1, 10, 100, and 1000 years after full-scale *in situ* fixation are shown in Table 12. In making these projections a monolith two to three feet thick and several hundred feet in extent was assumed. The upper surface was assumed to be dry and the lower surface was assumed to be in constant contact with slowly-moving groundwater. Under these conditions, it is projected that metal leaching would be slight; even after 1000 years less than 10 percent of each metal of interest would have been released. This projection does not account for changes in leachate alkalinity, however. It is likely that, after all soluble alkalinity had been released from the monolith, groundwater pH would fall and metal leaching would accelerate. Leaching of organic compounds (including phenols) from fixed soil and soil:fluff monoliths would also amount to less than 10 percent over 1000 years. Such leaching rates would result in undetectable levels of contaminants in the shallow groundwater. Phenols, naphthalene, and possibly other PAHs are projected to leach from a fixed soil:tar mix at higher rates, such that 50 percent or more would be released in 1000 years. Because they are very concentrated in the fixed material, these compounds might be detectable in slowly-moving shallow groundwater.

On the site, a fixed monolith is much more likely to experience alternating periods of wetting and drying than an unvarying hydrologic regime. How this variation would affect leaching is not well understood. Therefore, three ANS 16.1 leaching experiments were performed in conjunction with wet/dry durability stressing of the test cylinders. All cylinders were of the 3:1 soil:fluff mix. One cylinder was subjected to six days (four cycles) of wet/dry stressing, a second to 14 days (12 cycles) of stressing, and three cylinders underwent 22 days (20 cycles) of stressing. After these cycles, standard ANS leaching tests were performed. In addition, three unstressed cylinders of the 3:1 mix were subjected to ANS 16.1 extraction. During the wet/dry stressing, cylinders were dried at room temperature, not 60°C as was done in the engineering tests.

The ANS leachate pH and EC for the wet/dry stressed cylinders are shown in Figures 10 and 11, respectively. As expressed by these parameters, surface weathering of the cylinders was accelerated by cyclic wetting and drying. Leachate pH for the 12 and 20-cycle cylinders fell below 9 by the 15th day of the experiments, whereas leachates from the unstressed (see 3:1 curve on Figure 7) and 4-cycle cylinders did not fall below 9 until after the 28th day. Leachate conductivity showed a roughly similar trend. The cylinders subjected to 12 and 20 weathering cycles had relatively high - actually increasing - leachate EC values during the stressing periods. In leachates from unstressed or briefly-stressed (4 cycles) cylinders, EC diminished continuously from the beginning.

Table 12. Projected Leaching from an *In situ* Fixed Monolith

Material/	Year after	Cumulative Proportion Leached		
Parameter	fixation: 1	10	100	1000
Fixed Soil				
Arsenic	$<5.0x10^{-4}$	$<1.6x10^{-3}$	$<5x10^{-3}$	<0.016
Lead	$<2.5x10^{-3}$	$<7.9x10^{-3}$	$<2.5x10^{-2}$	<0.079
Phenols[a]	$2.8x10^{-3}$	$3.9x10^{-3}$	$7.3x10^{-3}$	0.018
Naphthalene	<0.080	<0.25	<0.80	-
Benzo(a)pyrene	$<8.9x10^{-4}$	$<2.8x10^{-3}$	$<8.9x10^{-3}$	<.028
PCBs	$<2.8x10^{-3}$	$<8.9x10^{-3}$	<0.028	<0.089
Fixed 1:1 Soil:Fluff				
Arsenic	$2.5x10^{-3}$	$7.9x10^{-3}$	0.025	0.079
Lead	$<8.0x10^{-4}$	$<2.5x10^{-3}$	$<8.0x10^{-3}$	<0.025
Phenols[a]	$6.3x10^{-3}$	$8.7x10^{-3}$	0.016	0.041
Pyrene	$<2.5x10^{-3}$	$<7.9x10^{-3}$	<0.025	<0.079
PCBs	$<6.3x10^{-4}$	$<2.0x10^{-3}$	$<6.3x10^{-3}$	<0.02
Fixed 1:1 Soil:Tar				
Phenols[a]	0.20	0.34	0.77	1
Naphthalene	0.022	0.071	0.22	0.71
Pyrene	$<1.4x10^{-3}$	$<4.5x10^{-3}$	<0.014	<0.045
Benzo(a)pyrene	$<1.4x10^{-4}$	$<4.5x10^{-4}$	$<1.4x10^{-3}$	$<4.5x10^{-3}$

a. Based on lowest leachability index calculated from ANS 16.1 testing; all others based on average index.

Note: projections are based on a number of assumptions (explained in text).

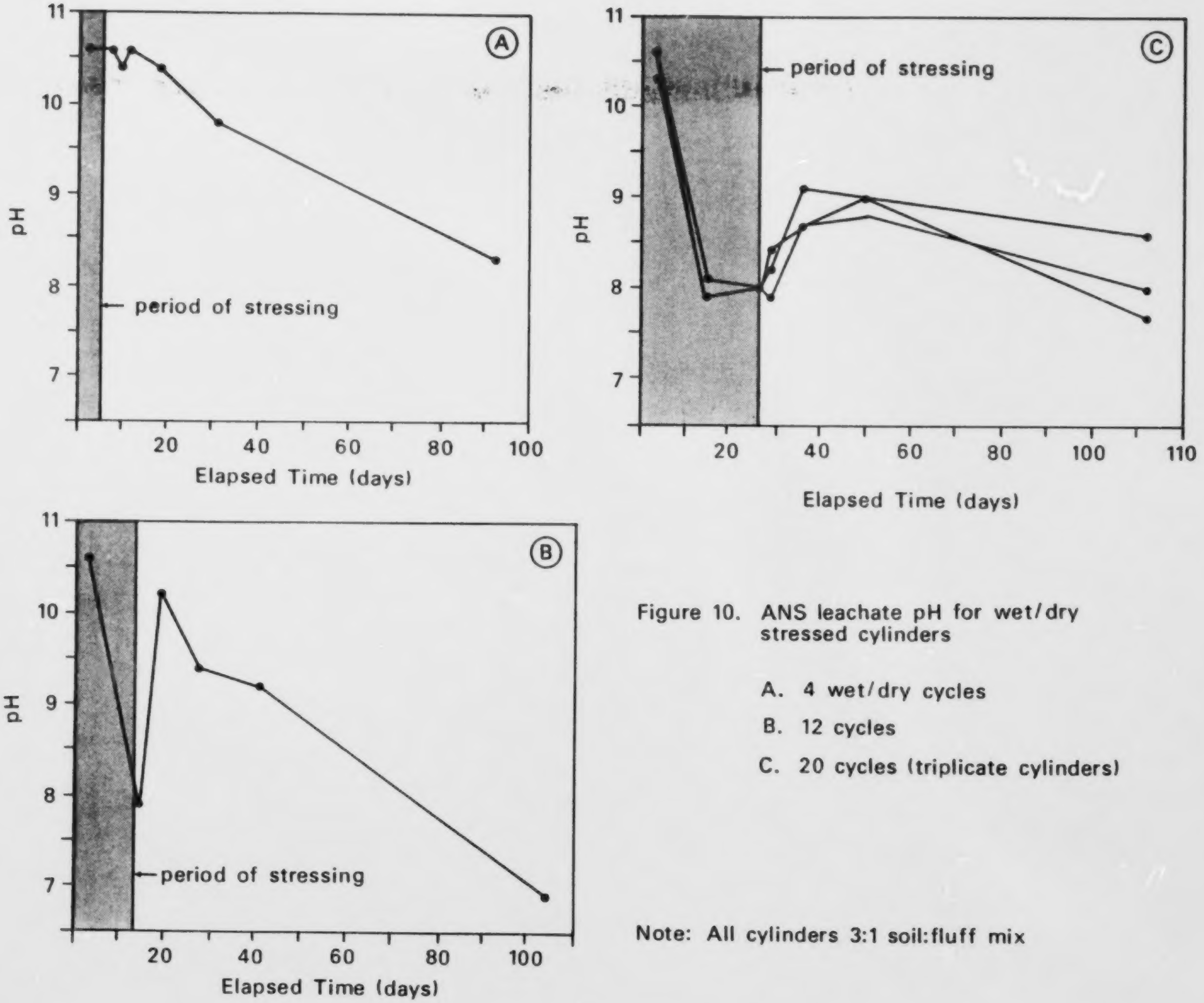


Figure 10. ANS leachate pH for wet/dry stressed cylinders

A. 4 wet/dry cycles

B. 12 cycles

C. 20 cycles (triplicate cylinders)

Note: All cylinders 3:1 soil:fluff mix

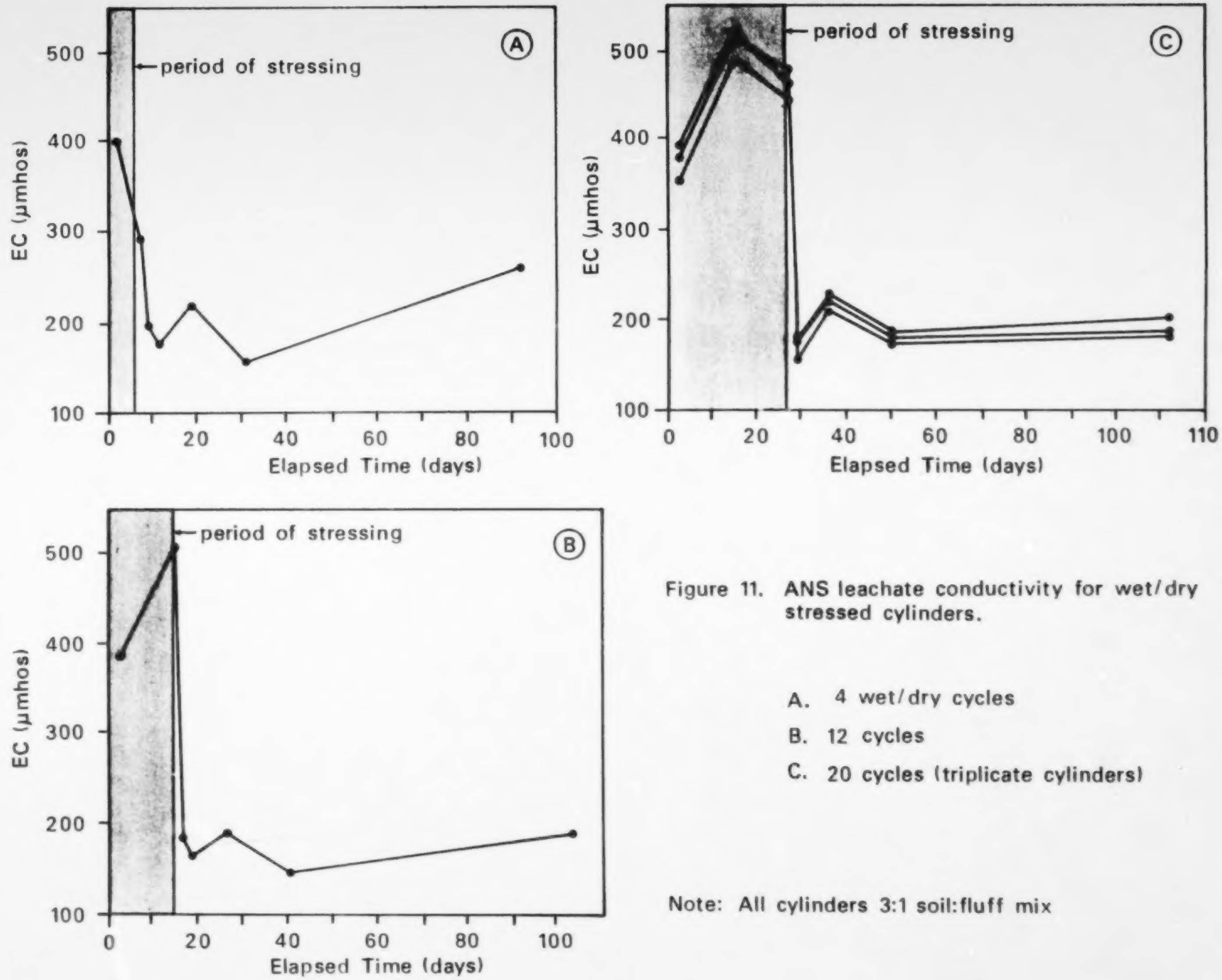


Figure 11. ANS leachate conductivity for wet/dry stressed cylinders.

A. 4 wet/dry cycles
B. 12 cycles
C. 20 cycles (triplicate cylinders)

Note: All cylinders 3:1 soil:fluff mix

Concentrations of individual contaminants in leachate cannot be interpreted to either confirm or contradict this apparent accelerated-weathering phenomenon. Because of the alkaline leaching conditions, leachate metals were generally undetectable, preventing comparisons among treatments. Among those quantified, there were no time trends in leachability index. Neither average leachability index nor total fraction leached differed among the stressing regimes for the metals. In the leachates from the 12 and 20-cycle tests, copper levels (which should have been quantified very precisely) showed perturbations over time, possibly connected with the cessation of wet-dry stressing.

Figure 12 traces leachate phenol concentrations over time. The leaching rate for total phenols decreased from the beginning to the end of every experiment (as measured by increased L). However, leaching increased for several days following the cessation of wet-dry stressing in the 12 and 20-cycle tests (the 20-cycle test was performed in triplicate and this trend was observed in every replicate). This short-term increase did not affect the average leachability of phenols or the total fraction leached. These statistics did not differ among the 0, 4, 12, and 20-cycle tests.

The PAHs and PCBs were originally present in the 3:1 soil:fluff mix at very low levels (see Table 5). PCBs were undetected (at 0.3 μg/L) in leachates from the wet-dry stressed cylinders, and individual PAHs were quantified in fewer than 10 instances. Based on the reported detection limits, the leaching rates for these contaminants in these tests were very low. The corresponding leachability indices were in the range of 12 - 15. Because of the low values no differences can be distinguished among the various stressing regimes.

Summary and Conclusions

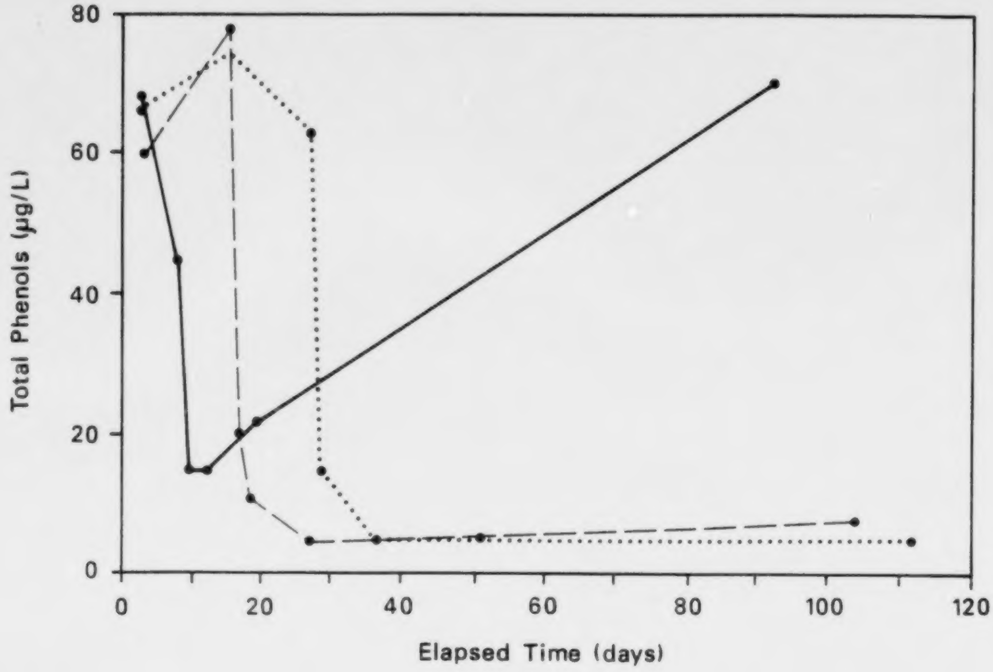
The cursory debris classification carried out at the Tar Pits showed that a considerable proportion of the surficial material there is too large to undergo stabilization/solidification without prior processing. No attempt was made to determine what proportion could be milled and what proportion would have to be segregated and treated or disposed.

Chemical-concentration data for site soil, tar, and auto fluff were in agreement with previously-collected data. For most contaminants in most site materials, very wide ranges of values have been reported. Although this study attempted to collect highly-contaminated samples, concentrations did not exceed those previously reported. The materials studied were representative for the site, not atypically contaminated.

Despite a twofold dilution, concentrations of many contaminants in fixed materials were reported to be as high or higher than those in the corresponding raw materials. This occurred because the concentrations were very low relative to instrument quantitation limits, limiting analytical precision. In treatability studies where this situation is foreseen, experimenters may consider spiking site samples with the contaminants of interest.

If considered as "soils," some of the site materials fixed according to this protocol would exceed Tar Pits site cleanup goals for lead and PAHs.

Fixation of site materials by these procedures resulted in approximate volume increases ranging from 45 percent (for fixed tar) to 95 percent (soil). These are much greater than documented volume changes at sites where fixation has been conducted. This reflects the high bulk density of the site soils and the very high reagent dosages used herein to assure effective fixation. Reagent dosages for full-scale remediation may be different.



——— 4 wet/dry cycles

— — 12 cycles

······· 20 cycles (mean of triplicate values)

Note: detection limit = 5 μg/L

Figure 12. Phenol concentrations in leachate from wet/dry stressed cylinders.

As measured by the wet/dry stress test, the durability of fixed soil and soil-fluff mixtures was acceptable. Fixed tar and tar-soil cylinders failed the durability test, possibly because cyclic drying was conducted at 60°C. High-temperature drying meant to simulate long time intervals, is inappropriate for materials containing a high proportion of volatile and semi-volatile compounds.

Tests of compressive strength vs. time showed the fixed cylinders were still gaining measurable strength after 29 days, when the "ultimate strength" of concrete is tested. Development of strength appears to be slowed in these heterogeneous materials, and later testing of ultimate strength (after 42 or 50 days) would be appropriate.

The inclusion of tar or auto fluff diminished the ultimate compressive strength of the fixed materials. Nonetheless, all fixed mixes except pure tar would probably meet site-specific strength standards, and would not be expected to collapse under their own weight. All wet/dry-stressed fixed materials were markedly stronger than their unstressed counterparts. The probable cause was drying at 60°C, which accelerated the curing process. Stressed fixed soil developed a compressive strength of 1380 psi.

The permeabilities of unstressed fixed materials ranged from 1.2×10^{-9} to 3.5×10^{-8} cm/sec. Neither auto fluff nor tar influenced permeability. Wet/dry stressing increased the permeability of all materials by more than an order of magnitude, probably by accelerating the development of micropores near the cylinders' surfaces. This implies that the physical breakdown of a full-scale monolith could be partially forestalled by preventing contact with groundwater.

One tar cylinder failed in compression at zero effective pressure and another cracked during stressing, indicating that fixed tar would probably have insufficient physical integrity to meet site remediation goals.

In TCLP testing of raw site materials, lead and phenols were readily extracted. Volatile compounds leached freely from coal tar. Some of the raw materials exceeded proposed TCLP standards for lead or benzene. Pure leachates also exceeded cleanup goals for these contaminants in site surface and groundwater. TCLP extraction of lead (and other heavy metals) was strongly curtailed by fixation. This phenomenon was studied by Bishop (1988) and shown to be caused by the leaching of alkaline fixation reagents. Undiluted TCLP leachates from fixed Tar Pits materials met site PAH standards. Leachates from fixed tar exceeded one of the site benzene goals, and other leachates exceeded lead goals.

In the 90-day ANS 16.1 tests of fixed materials, leachate pH and EC showed a strong initial flush of alkalinity from the solids. Most of the contaminants of interest had calculated leachability indices greater than 10, indicating relative immobility under mild leaching conditions. Leachability of these contaminants did not change with time, and less than three percent of each contaminant was extracted. The PAHs and PCBs were probably held by adsorption, and leaching of the heavy metals was solubility-controlled. Phenols behaved differently; they initially leached freely from the sample surfaces. By the end of the 90-day trials, their leaching rates were much slower, probably controlled by diffusion through the solid cylinders.

Long-term projections of leaching from *in situ* monoliths of various types were made. These indicate that low proportions of the contaminants of interest (probably undetectable in the shallow groundwater) would leach from fixed soil or soil-fluff mixes. The projections do not account for diminishing leachate alkalinity, and consequent increases in metal leaching. It was projected that phenols and some PAHs might be detectable in groundwater contacting a fixed 1:1 soil:tar monolith. Release of these constituents would be most marked in the early years after placement of the monolith. Projecting the actual concentrations in groundwater would require modeling the shallow aquifer using site-specific hydrologic data.

When wet/dry stressing was combined with ANS 16.1 leaching, weathering of the fixed cylinders was accelerated. Few effects on the leaching of the contaminants of interest could be discerned, chiefly because they were present at very low levels in all the leachates. Where effects could be inferred, they did not appear to persist after cyclic stressing ended. For future tests, it is suggested that contaminants be spiked into the materials to be fixed, and a control (no wet/dry stressing) be paired with a continuous, 90-day stressing and leaching test.

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Appendix A

Field Sample Data and Chain of Custody Sheet

Organic Traffic Report

Inorganic Traffic Report

Metals Analysis Form

Priority Pollutant Organics Analysis Form

ANS 16.1 Data Sheet

EPA
EPA Region 10
1200 Sixth Avenue
Seattle WA 98101

FIELD SAMPLE DATA AND CHAIN OF CUSTODY SHEET

Case No.: ______________
Project Code: __________ Account: __________
Name/Location ______________
(EPA Lab Only, Leave Blank for Contract Lab)
Proj. Off.: ______________ Tel.# __________

☐ Enforcement/Custody
☐ Data Confidential
☐ Possible Toxic/Hazardous
☐ Data for Storet

Miscellaneous: ______________

Sampling Crew: ______________

Recorder: ______________
(Signatures Required)

SOURCE CODE	MATRIX					# CONTAINERS							LAB NUMBER			STORET STATION NUMBER	SAMPLING DATE & TIME				TRAFFIC REPORT NUMBERS		SAMPLER'S INITIALS	STATION DESCRIPTION
	Oil	Water	Sediment	Tissue	Prsrvd(Y/N)	Qt. Cubit	Gal. Cubit	16 oz	8 oz.	120 ml	40 ml	Other	Yr	Wk	Seq		Yr	Mo	Dy	Time	Org.	Inorg.		

A-2

LAB NUMBER			DEPTH			COL MTD CD	QA CODE	TEMP DEG C	pH	CNDCTVTY umho/cm	COMPOSITE ONLY				
											ENDING DATE				
Yr	Wk	Seq		Units	Type						Mo	Dy	Time	Type	Freq

CONDITION OF SAMPLES UPON RECEIPT AT LAB:

CUSTODY SEALS INTACT: ☐ yes ☐ no ☐ none

CHAIN OF CUSTODY RECORD

RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	RECEIVED BY: (Signature)	DATE/TIME
RELINQUISHED BY: (Signature)	RECEIVED BY MOBILE LAB FOR FIELD ANALYSIS: (Signature)	DATE/TIME
DISPATCHED BY: (Signature) DATE/TIME	RECEIVED FOR LAB BY: (Signature)	DATE/TIME

METHOD OF SHIPMENT

Laboratory Copy White   Project Officer Copy Yellow   Field or Office Copy Pink   GPO 592-537

USEPA CONTRACT LABORATORY PROGRAM
SAMPLE MANAGEMENT OFFICE
P.O. BOX 818 ALEXANDRIA, VA 22313
703-557-2490 FTS 557-2490

CASE NO:

SAS NO:
(IF APPLICABLE)

ORGANIC TRAFFIC REPORT

(FOR CLP USE ONLY)

TYPE OF ACTIVITY (CIRCLE ONE) ①
SUPERFUND—PA SI ESI RIFS RD RA ER NPLD O&M OTHER ______
NON-SUPERFUND—____________PROGRAM

SITE NAME:

CITY, STATE: SITE SPILL ID:

REGION NO: **SAMPLING COMPANY** ②

SAMPLER: (NAME)

SHIP TO: ③

ATTN: ____________

SAMPLING DATE: ④

BEGIN: ____________ END: ____________

DATE SHIPPED: ______ **CARRIER:** ______ ⑤

AIRBILL NO: ____________

SAMPLE DESCRIPTION ⑥
(ENTER IN BOX A)
1. SURFACE WATER
2. GROUND WATER
3. LEACHATE
4. SOIL
5. SEDIMENT
6. OIL (SAS)
7. WASTE (SAS)

TRIPLE VOLUME REQUIRED FOR MATRIX SPIKE/DUPLICATE AQUEOUS SAMPLE

SHIP MEDIUM AND HIGH CONCENTRATION SAMPLES IN PAINT CANS

SEE REVERSE FOR ADDITIONAL INSTRUCTIONS

CLP SAMPLE NUMBER (FROM LABELS)	Ⓐ SAMPLE DESCRIPTION (FROM BOX 1) 1 2 3 4 5 6 7	Ⓑ CONCENTRATION L = LOW M = MED H = HIGH (SAS)	Ⓒ RAS ANALYSIS				Ⓓ SPECIAL HANDLING	Ⓔ STATION LOCATION
			VOLATILE	BASE/NEUT /ACID	PESTICIDE /PCB's			

EPA Form 2075-7 (8-87)

WHITE — SMO COPY PINK — CLIENT COPY WHITE — LAB COPY FOR RETURN TO SMO YELLOW — LAB COPY

A-3

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USEPA CONTRACT LABORATORY PROGRAM
SAMPLE MANAGEMENT OFFICE
P.O. BOX 818 ALEXANDRIA, VA 22313
703/557-2490 FTS 557-2490

CASE NO:

SAS NO:
(IF APPLICABLE)

INORGANIC TRAFFIC REPORT

(FOR CLP USE ONLY)

TYPE OF ACTIVITY (CIRCLE ONE) ①
SUPERFUND—PA SI ESI RIFS RD RA ER NPLD O&M OTHER ______
NON-SUPERFUND—__________PROGRAM

SITE NAME:

CITY, STATE:

SITE SPILL ID:

REGION NO: SAMPLING COMPANY ②

SAMPLER: (NAME)

SHIP TO: ③

ATTN: ______

SAMPLING DATE: ④
BEGIN: ______ END: ______

DATE SHIPPED: ______ CARRIER: ______ ⑤
AIRBILL NO: ______

SAMPLE DESCRIPTION ⑥
(ENTER IN BOX A)
1. SURFACE WATER
2. GROUND WATER
3. LEACHATE
4. SOIL
5. SEDIMENT
6. OIL (SAS)
7. WASTE (SAS)

DOUBLE VOLUME REQUIRED FOR MATRIX SPIKE/DUPLICATE AQUEOUS SAMPLE

SHIP MEDIUM AND HIGH CONCENTRATION SAMPLES IN PAINT CANS

SEE REVERSE FOR ADDITIONAL INSTRUCTIONS

CLP SAMPLE NUMBER (FROM LABELS)	Ⓐ SAMPLE DESCRIPTION (FROM BOX 1) 1 2 3 4 5 6 7	Ⓑ CONCENTRATION L = LOW M = MED H = HIGH (SAS)	Ⓒ RAS ANALYSIS							Ⓓ SPECIAL HANDLING	Ⓔ STATION LOCATION
			TOTAL METALS	CYANIDE	DISSOLVED METALS	HIGH ONLY (SAS)					
						SULFIDE	pH	CONDUCTIVITY	OXIDANTS		

EPA Form 2075-6 (8-87)

WHITE — SMO COPY PINK — CLIENT COPY WHITE — LAB COPY FOR RETURN TO SMO YELLOW — LAB COPY

A-4

(4)

EPA Region 10 Laboratory

Analyses Required
METALS

Project Name: ______________________ Project Code: ______________ Account Code: ______________

Matrix Codes *(circle one only)*

10 Water-Total
11 Water-Dissolved
40 Sediment/Soil
45 Semi-Solid/Sludge
46 Sediment for EP Toxicity
70 Tissue
80 Oil/Solvent
00 Other

Metals
(circle WG# and elements requiring analysis below)

Workgroup 30 - Standard Method
Workgroup 34 - EP Toxicity Method
Workgroup 47 - TCLP Method

		Sample Numbers																		Analy/Comp Init/Date
Aluminum	Al																			
Antimony	Sb																			
Arsenic	As																			
Barium	Ba																			
Beryllium	Be																			
Cadmium	Cd																			
Calcium	Ca																			
Chromium	Cr																			
*Chromium Hexavalent	Cr + 6																			
Cobalt	Co																			
Copper	Cu																			
Iron	Fe																			
Lead	Pb																			
Magnesium	Mg																			
Manganese	Mn																			
Mercury	Hg																			
Molybdenum	Mo																			
Nickel	Ni																			
Potassium	K																			
Selenium	Se																			
Silver	Ag																			
Sodium	Na																			
Thallium	Tl																			
Vanadium	V																			
Zinc	Zn																			

Save samples after analysis? **NONE** **†SOME** **†ALL** *(if SOME, circle sample numbers)*

* The Laboratory requires advance notice prior to receiving samples for Cr + 6.

Special Limits, methods and comments: ______________________________

Requester's Signature ______________________ *Date* ______________

†If samples should be saved, why? ______________________________

Note: Any Element may be determined by AA or ICP

A X-82 Lab Copy

A-5

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EPA Region 10 Laboratory **Analyses Required**

PRIORITY POLLUTANTS - ORGANICS

Project Name: ____________________ Project Code: ______________ Account Code: ______________

Matrix Codes *(circle one only)*

10 Water-Total
11 Water-Dissolved
40 Sediment/Soil
45 Semi-Solid/Sludge
46 Sediment for EP Toxicity
70 Tissue
80 Oil/Solvent
00 Other

Sample Numbers

Analy/Comp Init/Date

GC/MS Organics

51	Volatile Organics	VOA
62	Base/Neutrals Only	B/N
65	Acids Only	Acid
68	Base/Neutrals/Acids	B/N/A
60	Specific (GC/MS) Organics	list below

(additional space to list is provided below)

GC Organics

42	EDB	EDB
53	Trihalomethanes	Trihal
54	Purgeable halocarbons	Purg
71	Pesticide/PCB's	Pest/PCB
72	Pesticides Only	Pest
73	Herbicides *(List each/circle on reverse)*	
74	PCB's Only	PCB
77	Organophosphate Pesticides	*(List each)*
70	Specific Pesticides	*(List each)*
60	Specific (GC/MS) Organics	*(List each)*

(additional space to list is provided below)

Specific Organics/Other Miscellaneous

40	PolyAromHydro (HPLC)	PAH
67	Oil Identification	Oil-Id

(additional space to list is provided below)

Save samples after analysis? **NONE** **†SOME** **†ALL** *(if SOME, circle sample numbers)*

List any additional specific organics:

Special detection Limits and comments: ______________________________

Requester's Signature

†If samples should be saved, why? ______________________________

X-81 Lab Copy

A-5.a

ANS 16.1 DATA SHEET

Tacoma Tar Sample#________________

Sample Description________________

Initial Sample mass________________gr.

Start Date/Time________________

Initial surface area________________cm^2

Length________________cm

Scheduled leachate sampling	Actual sampling date/time	Sampler's signature	pH of leachate	EC of leachate	Leachate sample number	Volume of replacement D.I. water

Comments:

APPENDIX B

Chemical Concentration Data

Table Number Page

B1 Contaminant concentrations in raw sand (blank) B-4
B2 Contaminant concentrations in raw soil B-5
B3 Contaminant concentrations in raw tar B-6
B4 Contaminant concentrations in raw 1:1 soil:fluff B-7
B5 Contaminant concentrations in raw 3:1 soil:fluff B-8
B6 Contaminant Concentrations in TCLP leachate from raw sand (blank) B-9
B7 Contaminant Concentrations in TCLP leachate from raw soil B-10
B8 Contaminant Concentrations in TCLP leachate from raw tar B-11
B9 Contaminant Concentrations in TCLP leachate from raw 1:1 soil:tar B-12
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Data Qualifiers and Descriptors

U	Parameter was analyzed but not detected. Concentration shown is the applicable detection limit.
J	Estimated value. Either the value was less than the quantitation limit but greater than zero (in the B/N/A scan, peak area could not be integrated), or laboratory QA/QC shortcomings were identified for this sample, during the data validation.
UJ	Parameter was analyzed but not detected; value shown is the approximate detection limit.
R	Data unusable. Sample never analyzed, or associated QA/QC sample results were seriously out of bounds.

Sample analyses were conducted between January 1988 and August 1988 according to the Statements of Work for the Contract Laboratory Program. Data validation assessed laboratory performance in meeting the quality control specifications outlined in the Statements of Work for Inorganic Analysis (Revision 12/87) and Organic Analysis (Revision 2/88).

Table B1. Contaminant Concentrations in Raw Sand (Blank)

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	9.0	1.0
Cadmium	1.0UJ	1.0
Chromium	18.1	1.0
Copper	11.0	2.5
Lead	1.8J	0.5
Silver	0.86J	1.0
Zinc	23.4	2.0
Selenium	0.4UJ	0.4
Mercury	0.1UJ	0.1
Phenols	mg/kg	mg/kg
Total phenols	100U	100
Volatile Compounds	µg/kg	µg/kg
Benzene	5UJ	5
Toluene	5J	5
Total xylenes	6J	5
Ethylbenzene	2J	5
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	All "undetected" at 330 µg/kg (UJ)	
2-Methylnaphthalene		
Acenapthylene		
Fluorene		
Phenanthrene		
Fluoranthene		
Pyrene		
Benzo(a)anthracene		
Benzo(b)fluoranthene		
Benzo(k)fluoranthene		
Benzo(a)pyrene		
Indeno(1,2,3-cd)pyrene		
Dibenz(a,h)anthracene		
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221, 1232, 1242, 1248	79UJ	79
Aroclors 1254, 1260	160UJ	160

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[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

Table B2. Contaminant Concentrations in Raw Soil

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	137	1
Cadmium	24.2J	0.5
Chromium	366	1
Copper	3810	2.5
Lead	2490J	0.5
Silver	19.2J	1
Zinc	3090	2
Selenium	5.0UJ	5.0
Mercury	1.6J	0.02
Phenols	mg/kg	mg/kg
Total Phenols	377	100
Volatile Compounds	µg/kg	µg/kg
Benzene	2J	6
Toluene	8J	6
Total xylenes	8J	6
Ethylbenzene	1J	6
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	540J	All 1700
2-Methylnaphthalene	1300J	
Acenapthylene	2700J	
Fluorine	1600J	
Phenanthrene	4600J	
Fluoranthene	4200J	
Pyrene	8300J	
Benzo(a)anthracene	3400J	
Benzo(b)fluoranthene	2600J	
Benzo(k)fluoranthene	2300J	
Benzo(a)pyrene	3000J	
Indeno(1,2,3-cd)pyrene	1300J	
Dibenz(a,h)anthracene	900J	
PCBs	µg/kg	µg/kg
Aroclors 1016,1221, 1248	2000UJ	2000
Aroclor 1242	1400J	2000
Aroclor 1254	2700J	4000
Aroclor 1260	2100J	4000

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[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

Table B3. Contaminant Concentration in Raw Tar

Parameter	Concentration	Approximate Detection Limit
Metals	mg/kg	mg/kg
Arsenic		
Cadium		
Chromium		
Copper		
Lead	Metals data missing - sample lost	
Silver		
Zinc		
Selenium		
Mercury		
Phenols	mg/kg	mg/kg
Total phenols	201	100
Volatile Compounds	µg/kg	µg/kg
Benzene	69,000R	14,000
Toluene	160,000R	14,000
Total Xylenes	160,000R	14,000
Ethylbenzene	15,000R	14,000
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	14,000,000J	
2-Methylnaphthalene	14,000,000J	
Acenapthylene	4,500,000J	
Fluorine	3,400,000J	
Phenanthrene	7,400,000J	
Fluoranthene	1,900,000J	
Pyrene	3,200,000J	All 950,000
Benzo(a)anthracene	1,200,000J	
Benzo(b)fluoranthene	350,000J	
Benzo(k)fluoranthene	510,000J	
Benzo(a)pyrene	740,000J	
Indeno(1,2,3-cd)pyrene	240,000J	
Dibenz(a,h)anthracene	200,000J	
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221, 1232, 1242, 1248	22,000UJ	22,000
Aroclors 1254, 1260	44,000UJ	44,000

Table B4. Contaminant Concentrations in Raw 1:1 Soil:Fluff

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	61.9	1
Cadmium	36.5J	0.5
Chromium	299	1
Copper	2020	2.5
Lead	3080J	0.5
Silver	14.8J	1
Zinc	6060	2
Selenium	4.4J	0.5
Mercury	3.4J	0.02
Phenols	mg/kg	mg/kg
Total Phenols	584	100
Volatile Compounds	µg/kg	µg/kg
Benzene	7UJ	7
Toluene	7UJ	7
Total xylenes	7UJ	7
Ethylbenzene	7UJ	7
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	300J	All 1800
2-Methylnaphthalene	440J	
Acenapthylene	2000J	
Fluorene	1100J	
Phenanthrene	1400J	
Fluoranthene	2100J	
Pyrene	4200J	
Benzo(a)anthracene	1800UJ	
Benzo(b)fluoranthene	2500J	
Benzo(k)fluoranthene	1800UJ	
Benzo(a)pyrene	1400J	
Indeno(1,2,3-cd)pyrene	1100J	
Dibenz(a,h)anthracene	560J	
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221	5500UJ	5500
Aroclor 1232	9700J	5500
Aroclor 1242	5800J	5500
Aroclor 1248	5600J	5500
Aroclor 1254	7500J	11,000
Aroclor 1260	3800J	11,000

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[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

Table B5. Contaminant Concentration in Raw 3:1 Soil:Fluff

Parameter	Concentration[a]	Approximate Detection Limit[b]
Metals	mg/kg	mg/kg
Arsenic	141±14	1
Cadmium	27.8±4.5J	0.5
Chromium	364±61	1
Copper	2480±280	2.5
Lead	2120±134J	0.5
Silver	11.6±1.3J	1
Zinc	5170±1710	2
Selenium	17±13J	5.0
Mercury	3.4±2.0J	0.02
Phenols	mg/kg	mg/kg
Total phenols	389±66	100
Volatile Compounds	µg/kg	µg/kg
Benzene	7UJ	7
Toluene	7UJ	7
Total xylenes	7UJ	7
Ethylbenzene	7UJ	7
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	453±210J	All 1700
2-Methylnaphthalene	717±421J	
Acenapthylene	3770±1630J	
Fluorene	1930±404J	
Phenanthrene	4000±2360J	
Fluoranthene	4270±1940J	
Pyrene	7400±4080J	
Benzo(a)anthracene	1700UJ	
Benzo(b)fluoranthene	2770±1360J	
Benzo(k)fluoranthene	1830±611J	
Benzo(a)pyrene	2630±1140J	
Indeno(1,2,3-cd)pyrene	1420±470J	
Dibenz(a,h)anthracene	840±177J	
PCBs	µg/kg	µg/kg
Aroclors 1016,1221, 1232,1248	5200UJ	5200
Aroclor 1242	3430±510J	5200
Aroclor 1254	5470±150J	10,400
Aroclor 1260	4530±1470J	10,400

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[a] Results from analysis of triplicate samples, plus/minus the standard deviation. Below-detection values are incorporated as the detection limit.

[b] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

Table B6. Contaminant Concentrations in TCLP Leachate from Raw Sand (Blank)

Parameter	Concentration(μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	50UJ	50
Cadmium	5U	5
Chromium	10U	10
Copper	62	25
Lead	71	5
Silver	2.9	0.2
Zinc	761	20
Selenium	1U	1
Mercury	0.05U	0.05
Phenols		
Total phenols[a]	303U	285
Volatile Compounds		
Benzene	5UJ	5
Toluene	2J	5
Total xylenes	2J	5
Ethylbenzene	5UJ	5
Polycyclic Aromatics		
Naphthalene	0.4J	9
2-Methylnaphthalene	9U	9
Acenapthylene	9U	9
Fluorene	9U	9
Phenanthrene	9U	9
Fluoranthene	9U	9
Pyrene	9U	9
Benzo(a)anthracene	9U	9
Benzo(b)fluoranthene	9U	9
Benzo(k)fluoranthene	9U	9
Benzo(a)pyrene	9U	9
Indeno(1,2,3-cd)pyrene	9U	9
Dibenz(a,h)anthracene	9U	9
PCBs		
Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260	0.1U	0.1

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[a] Total of individual phenols reported from the B/N/A scan.

Table B7. Contaminant Concentrations in TCLP Leachate from Raw Soil

Parameter	Concentration(μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	164J	10
Cadmium	843	5
Chromium	206	10
Copper	9180	25
Lead	51,000	5
Silver	0.5	0.2
Zinc	117,600	20
Selenium	1U	1
Mercury	0.05U	0.05
Phenols		
Total Phenols[a]	135U	120
Volatile Compounds		
Benzene	5UJ	5
Toluene	3J	5
Total xylenes	5UJ	5
Ethylbenzene	5UJ	5
Polycyclic Aromatics		
Naphthalene	0.2J	All 4
2-Methylnaphthalene	4U	
Acenapthylene	4U	
Fluorene	4U	
Phenanthrene	0.1J	
Fluoranthene	4U	
Pyrene	4U	
Benzo(a)anthracene	4U	
Benzo(b)fluoranthene	4U	
Benzo(k)fluoranthene	4U	
Benzo(a)pyrene	4U	
Indeno(1,2,3-cd)pyrene	4U	
Dibenz(a,h)anthracene	4U	
PCBs		
Aroclors 1016, 1221, 1242, 1248, 1254	0.05U	0.05
Aroclor 1260	0.06	0.05

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[a] Total of individual phenols reported from the B/N/A scan.

Table B8. Contaminant Concentrations in TCLP Leachate from Raw Tar

Parameter	Concentration(μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	1U	1
Cadmium	5U	5
Chromium	10U	10
Copper	62	25
Lead	165	5
Silver	0.2U	0.2
Zinc	1060	20
Selenium	1U	1
Mercury	0.05U	0.05
Phenols		
Total phenols	5250	250
Volatile Compounds		
Benzene	200J	5
Toluene	330J	5
Total xylenes	94J	5
Ethylbenzene	16J	5
Polycyclic Aromatics		
Naphthalene	1100	All 26
2-Methylnaphthalene	310	
Acenapthylene	26U	
Fluorene	78	
Phenanthrene	77	
Fluoranthene	26U	
Pyrene	26U	
Benzo(a)anthracene	26U	
Benzo(b)fluoranthene	3J	
Benzo(k)fluoranthene	26U	
Benzo(a)pyrene	25U	
Indeno(1,2,3-cd)pyrene	26U	
Dibenz(a,h)anthracene	26U	
PCBs		
Aroclors 1016, 1221, 1232 1242, 1248, 1254, 1260	0.3U	0.3

Table B9. Contaminant Concentrations in TCLP Leachate from Raw 1:1 Soil:Fluff

Parameter	Concentration(μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	131J	10
Cadmium	206	5
Chromium	234	10
Copper	16,400	25
Lead	12,520	5
Silver	0.2U	0.2
Zinc	58,600	20
Selenium	1U	1
Mercury	0.05U	0.05
Phenols		
Total phenols[a]	139U	125
Volatile Compounds		
Benzene	5UJ	5
Toluene	0.9J	5
Total xylenes	5UJ	5
Ethylbenzene	5UJ	5
Polycyclic Aromatics		
Naphthalene	0.6J	4
2-Methylnaphthalene	0.2J	4
Acenapthylene	0.2J	4
Fluorene	0.4J	4
Phenanthrene	0.2J	4
Fluoranthene	4U	4
Pyrene	4U	4
Benzo(a)anthracene	4U	4
Benzo(b)fluoranthene	4U	4
Benzo(k)fluoranthene	4U	4
Benzo(a)pyrene	4U	4
Indeno(1,2,3-cd)pyrene	4U	4
Dibenz(a,h)anthracene	4U	4
PCBs		
Aroclors 1016, 1221, 1232, 1242, 1248, 1254, 1260	0.05U	0.05

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[a] Total of individual phenols reported from the B/N/A scan.

Table B10. Contaminant Concentrations in TCLP Leachate from Raw 3:1 Soil:Fluff.

Parameter	Concentration(μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	138±50J	10
Cadmium	472±91	5
Chromium	226±20	10
Copper	11,080±1930	25
Lead	44,290±26,190	5
Silver	0.2U	0.2
Zinc	94,550±14,540	20
Selenium	1U	1
Mercury	0.05U	0.05
Phenols		
Total phenols[a]	161U	145
Volatile Compounds		
Benzene	5UJ	5
Toluene	0.6±0.3J	5
Total xylenes	5UJ	5
Ethylbenzene	5UJ	5
Polycyclic Aromatics		
Naphthalene	0.5±0.1J	
2-Methylnaphthalene	0.2±0J	
Acenapthylene	0.2±0.1J	
Fluorene	0.1±0.1J	
Phenanthrene	0.2±0.1J	
Fluoranthene	4U	All 4
Pyrene	0.2J±0.1	
Benzo(a)anthracene	4U	
Benzo(b)fluoranthene	4U	
Benzo(k)fluoranthene	4U	
Benzo(a)pyrene	4U	
Indeno(1,2,3-cd)pyrene	4U	
Dibenz(a,h)anthracene	4U	
PCBs		
Aroclors 1016, 1221, 1232 1242, 1248, 1254	0.05U	0.05
Aroclor 1260	0.12±0.05	0.05

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[a] Total of individual phenols reported from the B/N/A scan.

Note: Concentrations are the average from analyses of three samples, plus/minus the standard deviation.

Table B11. Contaminant Concentrations in Fixed Sand (Blank)

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	0.85UJ	0.85
Cadmium	1.1U	1.1
Chromium	37.3J	1
Copper	11.1J	2.5
Lead	10.2J	0.5
Silver	1.0UJ	1
Zinc	41.3J	2
Selenium	0.36UJ	0.36
Mercury	0.1UJ	0.1
Phenols	mg/kg	mg/kg
Phenol	1.4	0.39
All others[b]	12.6U	12.6
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	1400J	390
2-Methylnaphthalene	630J	390
Acenapthylene	140J	390
Fluorene	390UJ	390
Phenanthrene	290J	390
Fluoranthene	390UJ	390
Pyrene	54J	390
Benzo(a)anthracene	390UJ	390
Benzo(b)fluoranthene	390UJ	390
Benzo(k)fluoranthene	390UJ	390
Benzo(a)pyrene	390UJ	390
Indeno(1,2,3-cd)pyrene	390UJ	390
Dibenz(a,h)anthracene	390UJ	390
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221, 1232, 1242, 1248	39UJ	39
Aroclors 1254, 1260	78UJ	78

[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

[b] Total of individual phenols reported from the B/N/A scan.

Note: Volatile compounds were not analyzed in fixed samples.

Table B12. Contaminant Concentrations in Fixed Soil.

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	354J	1
Cadmium	6.5	0.5
Chromium	247J	1
Copper	1410J	2.5
Lead	877J	0.5
Silver	1.6J	1
Zinc	1220	2
Selenium	1.4J	0.5
Mercury	0.91J	0.02
Phenols	mg/kg	mg/kg
Total phenols[b]	1450J	1450
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	4000J	All 51,000
2-Methylnaphthalene	51,000UJ	
Acenapthylene	51,000UJ	
Fluorene	51,000UJ	
Phenanthrene	8600J	
Fluoranthene	6400J	
Pyrene	17,000J	
Benzo(a)anthracene	7200J	
Benzo(b)fluoranthene	51,000UJ	
Benzo(k)fluoranthene	51,000UJ	
Benzo(a)pyrene	6000J	
Indeno(1,2,3-cd)pyrene	51,000UJ	
Dibenz(a,h)anthracene	51,000UJ	
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221, 1232, 1242	640UJ	640
Aroclor 1248	1600	640
Aroclor 1254	1300UJ	1300
Aroclor 1260	5000	1300

[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

[b] Total of individual phenols reported from the B/N/A scan.

Note: Volatile compounds were not analyzed in fixed samples

Table B13. Contaminant Concentrations in Fixed Tar

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	2.8J	1
Cadmium	1.0U	1.0
Chromium	37.7J	1
Copper	29.5J	2.5
Lead	52.3J	0.5
Silver	0.96UJ	0.96
Zinc	103J	2
Selenium	1.8UJ	1.8
Mercury	0.1UJ	0.1
Phenols	mg/kg	mg/kg
2,4-Dimethylphenol	44J	310
All others[b]	1050U	1050
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	8,100,000J	620,000
2-Methylnaphthalene	7,600,000J	620,000
Acenapthylene	2,900,000J	620,000
Fluorene	2,700,000J	620,000
Phenanthrene	4,800,000J	620,000
Fluoranthene	1,200,000J	620,000
Pyrene	2,600,000J	620,000
Benzo(a)anthracene	810,000J	620,000
Benzo(b)fluroanthene		310,000
Benzo(k)fluoranthene	sum = 870,000J	310,000
Benzo(a)pyrene	800,000J	310,000
Ideno(1,2,3-cd)pyrene	330,000J	310,000
Dibenz(a,h)anthracene	140,000J	310,000
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221 1232,1242, 1248	3100UJ	3100
Aroclors 1254, 1260	6200UJ	6200

[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

[b] Total of individual phenols reported from the B/N/A scan.

Note: Volatile compounds were not analyzed in fixed samples.

Table B14. Contaminant Concentrations in Fixed 1:1 Soil:Tar

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	27.5J	1
Cadmium	2.3	0.5
Chromium	1120J	1
Copper	671J	2.5
Lead	410J	0.5
Silver	1.9J	1
Zinc	647J	2
Selenium	0.35UJ	0.35
Mercury	0.4J	0.02
Phenols	mg/kg	mg/kg
Total Phenols[b]	5050U	5050
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	3,700,000J	300,000
2-Methylnaphthalene	3,600,000J	300,000
Acenapthylene	1,500,000J	300,000
Fluorene	1,400,000J	300,000
Phenanthrene	2,700,000J	300,000
Fluoranthene	670,000J	300,000
Pyrene	1,100,000J	300,000
Benzo(a)anthracene	490,000J	300,000
Benzo(b)fluoranthene	sum = 350,000	150,000
Benzo(k)fluoranthene		150,000
Benzo(a)pyrene	290,000J	150,000
Indeno(1,2,3-cd)pyrene	90,000J	150,000
Dibenz(a,h)anthracene	47,000J	150,000
PCBs	µg/kg	µg/kg
Aroclors 1016, 1221, 1232,1242,1248	7400UJ	7400
Aroclors 1254, 1260	15,000UJ	15,000

[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are Listed.

[b] Total of individual phenols reported from the B/N/A scan.

Note: Volatile compounds were not analyzed in fixed samples.

Table B15. Contaminant Concentrations in Fixed 1:1 Soil:Fluff

Parameter	Concentration	Approximate Detection Limit[a]
Metals	mg/kg	mg/kg
Arsenic	58.0J	1
Cadmium	32.6	0.5
Chromium	194J	1
Copper	16,600J	2.5
Lead	2770J	0.5
Silver	1.2J	1
Zinc	10,500J	2
Selenium	1.8UJ	1.8
Mercury	1.6J	0.02
Phenols	mg/kg	mg/kg
Total phenols[b]	1970U	1970
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	58,000UJ	
2-Methylnaphthalene	58,000UJ	
Acenapthylene	58,000UJ	
Fluorene	58,000UJ	
Phenanthrene	58,000UJ	All 58,000
Fluoranthene	7300J	
Pyrene	14,000J	
Benzo(a)anthracene	58,000UJ	
Benzo(b)fluoranthene	58,000UJ	
Benzo(k)fluoranthene	58,000UJ	
Benzo(a)pyrene	58,000UJ	
Indeno(1,2,3-cd)pyrene	58,000UJ	
Dibenz(a,h)anthracene	58,000UJ	
PCBs	µg/kg	µg/kg
Aroclors 1016,1221,1232, 1242	720UJ	720
Aroclor 1248	5200	720
Aroclor 1254	1400UJ	1400
Aroclor 1260	11,000	1400

[a] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

[b] Total of individual phenols reported from the B/N/A scan.

Note: Volatile compounds were not analyzed in fixed samples.

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Table B16. Contaminant Concentrations in Fixed 3:1 Soil:Fluff

Parameter	Concentration[a]	Approximate Detection Limit[b]
Metals	mg/kg	mg/kg
Arsenic	55.8±1.1J	1
Cadmium	15.9±6.6	0.5
Chromium	264±32J	1
Copper	2650±1240J	2.5
Lead	1790±330J	0.5
Silver	1.11±0.35UJ	1.0
Zinc	3550±1680J	2
Selenium	1.4±0.8J	0.5
Mercury	2.4±2.1J	0.02
Phenols	mg/kg	mg/kg
Total phenols[c]	1900U	1900
Polycyclic Aromatics	µg/kg	µg/kg
Naphthalene	56,000UJ	All 56,000
2-Methylnaphthalene	56,000UJ	
Acenapthylene	56,000UJ	
Fluorene	56,000UJ	
Phenanthrene	7250±780J	
Fluoranthene	7070±2060J	
Pyrene	13,200±3270J	
Benzo(a)anthracene	56,000UJ	
Benzo(b)fluoranthene	56,000UJ	
Benzo(k)fluoranthene	56,000UJ	
Benzo(a)pyrene	4200±420J	
Indeno(1,2,3-cd)pyrene	56,000UJ	
Dibenz(a,h)anthracene	56,000UJ	
PCBs	µg/kg	µg/kg
Aroclors 1016,1221 1232,1242	700UJ	700
Aroclor 1248	2870±680	700
Aroclor 1254	1400UJ	1400
Aroclor 1260	5930±1410	1400

[a] Results from analyses of three cylinders, plus/minus the standard deviation.

[b] Applicable detection limits for metals are unavailable; for metals above detection, the Contract Required Detection Limits are listed.

[c] Total of individual phenols reported from the B/N/A scan.

Note: Volatile compounds were not analyzed in fixed samples.

Table B17. Contaminant Concentrations in TCLP Leachate from Fixed Sand (Blank)

Parameter	Concentration (µg/L)	Approximate Detection Limit(µg/L)
Metals		
Arsenic	R	-
Cadmium	0.1U	0.1
Chromium	R	-
Lead	R	1
Silver	R	0.1
Selenium	R	1
Mercury	0.08U	0.08
Zinc	R	-
Phenols		
Phenol	22J	36
All others[a]	1152U	1152
Polycyclic Aromatics		
Naphthalene	All "undetected" at 36 µg/L	
2-Methylnaphthalene		
Acenapthylene		
Fluorene		
Phenanthrene		
Fluoranthene		
Pyrene		
Benzo(a)anthracene		
Benzo(b)fluoranthene		
Benzo(k)fluoranthene		
Benzo(a)pyrene		
Indeno(1,2,3-cd)pyrene		
Dibenz(a,h)anthracene		

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[a] Total of individual phenols reported from the B/N/A scan.

Table B18. Contaminant Concentrations in TCLP Leachate from Fixed Soil

Parameter	Concentration (μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	2.0	-
Cadmium	7.0	0.1
Chromium	3	-
Lead	17	1
Silver	1.6J	0.1
Selenium	1U	1
Mercury	0.08U	0.08
Zinc	R	-
Phenols		
Total phenols[a]	418U	418
Polycyclic Aromatics		
Naphthalene	2J	
2-Methylnaphthalene	12U	
Acenapthalene	12U	
Fluorene	12U	
Phenanthrene	12U	
Fluoranthene	12U	All 12
Pyrene	12U	
Benzo(a)anthracene	12U	
Benzo(b)fluoranthene	12U	
Benzo(k)fluoranthene	12U	
Benzo(a)pyrene	12U	
Indeno(1,2,3-cd)pyrene	12U	
Dibenz(a,h)anthracene	12U	

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[a] Total of individual phenols reported from the B/N/A scan.

Table B19. Contaminant Concentrations in TCLP Leachate from Fixed Tar

Parameter	Concentration (µg/L)	Approximate Detection Limit(µg/L)
Metals		
Arsenic	2	-
Cadmium	10.1	0.1
Chromium	13	-
Lead	1U	1
Silver	0.1U	0.1
Selenium	1U	1
Mercury	0.1	0.08
Zinc	R	-
Phenols		
Phenol	420	120
All others[a]	4790U	3890
Volatile Compounds		
Benzene	537	5
Toluene	1000	5
Total Xylenes	674	5
Ethylbenzene	82	5
Polycyclic Aromatics		
Naphthalene	3100	120
2-Methylnaphthalene	1200	120
Acenapthylene	360	120
Fluorene	89J	120
Phenanthrene	80J	120
Fluoranthene	120U	120
Pyrene	4J	12
Benzo(a)anthracene	12U	12
Benzo(b)fluoranthene	12U	12
Benzo(k)fluoranthene	12U	12
Benzo(a)pyrene	12U	12
Indeno(1,2,3-cd)pyrene	12U	12
Dibenz(a,h)anthracene	12U	12

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[a] Total of individual phenols reported from the B/N/A scan.

Table B20. Contaminant Concentrations in TCLP Leachate from Fixed 1:1 Soil:Tar

Parameter	Concentration (µg/L)	Approximate Detection Limit (µg/L)
Metals		
Arsenic	4	-
Cadmium	1.4	0.1
Chromium	35	-
Lead	1U	1
Silver	0.1U	0.1
Selenium	1U	1
Mercury	0.08U	0.08
Zinc	R	-
Phenols		
Phenol	460	120
2-MethylphenoL	170	12
4-Methylphenol	550	120
All others[a]	377U	360
Volatile Compounds		
Benzene	59	24
Toluene	540	24
Total Xylenes	505	24
Ethylbenzene	55	24
Polycyclic Aromatics		
Naphthalene	3100	120
2-Methylnapthalene	1200	120
Acenapthylene	330	12
Fluorene	110	12
Phenanthrene	71	12
Fluoranthene	4J	12
Pyrene	5J	12
Benzo(a)anthracene	12U	12
Benzo(b)fluoranthene	12U	12
Benzo(k)fluoranthene	12U	12
Benzo(a)pyrene	12U	12
Indeno(1,2,3-cd)pyrene	12U	12
Debenz(a,h)anthracene	12U	12

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[a] Total of individual phenols reported from the B/N/A scan.

Table B21. Contaminant Concentrations in TCLP Leachate from Fixed 1:1 Soil:Fluff

Parameter	Concentration ($\mu g/L$)	Approximate Detection Limit($\mu g/L$)
Metals		
Arsenic	8	-
Cadmium	10.1	0.1
Chromium	6	-
Lead	23	1
Silver	0.4	0.1
Selenium	1U	1
Mercury	0.2	0.08
Zinc	R	-
Phenols		
Phenol	23	13
All others[a]	412U	412
Polycyclic Aromatics		
Naphthalene	6J	All 13
2-Methylnaphthalene	1J	
Acenapthylene	13U	
Fluorene	13U	
Phenanthrene	13U	
Fluoranthene	13U	
Pyrene	13U	
Benzo(a)anthracene	13U	
Benzo(b)fluoranthene	13U	
Benzo(k)fluoranthene	13U	
Benzo(a)pyrene	13U	
Indeno(1,2,3-cd)pyrene	13U	
Dibenz(a,h)anthracene	13U	

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[a] Total of individual phenols reported from the B/N/A scan.

Table B22. Contaminant Concentrations in TCLP Leachate from Fixed 3:1 Soil:Fluff

Parameter	Concentration[a] (μg/L)	Approximate Detection Limit(μg/L)
Metals		
Arsenic	6.3±0.6	-
Cadmium	5.0±2.3	0.1
Chromium	12.5±3.5	-
Lead	11±8.7	1
Silver	0.17±0.12U	0.1
Selenium	4±1	
Mercury	0.11±0.05U	0.08
Zinc	R	-
Phenols		
Phenol	15±4J	36
All others[b]	2046U	2046
Polycyclic Aromatics		
Naphthalene	6.3±6.7J	All 62
2-Methylnaphthalene	62U	
Acenapthylene	62U	
Fluorene	62U	
Phenanthrene	62U	
Fluoranthene	62U	
Phenanthrene	62U	
Pyrene	62U	
Fluoranthene	62U	
Benzo(a)anthracene	62U	
Benzo(b)fluoranthene	62U	
Benzo(k)fluoranthene	62U	
Benzo(a)pyrene	62U	
Indeno(1,2,3-cd)pyrene	62U	

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[a] Results from analyses of three cylinders, plus/minus the standard deviation.

[b] Total of individual phenols reported from the B/N/A scan.

Table B23. Contaminant concentrations in ANS leachate from soil and soil-fluff mixtures

Fixed Material	Elapsed Time (Days)	Concentration (µg/L)				
		Arsenic	Mercury	Selenium	Silver	Cadmium
Soil	1	50U	0.05	1U	4U	5U
	3	2	0.05U	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.05U	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	6J	0.05	10	0.2U	5U
	90	16	0.08U	16	0.2U	5U
1:1 Soil: Fluff	1	50U	0.05U	1U	4U	5U
	3	3J	0.1	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.005U	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	1U	0.05	5	0.2U	5U
	90	2	0.08U	17	0.2U	5U
3:1 Soil: Fluff	1	50UJ	0.11	1U	4U	5U
	3	4	0.1	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.05U	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	3	0.05	10	0.2U	5U
	90	1U	0.08U	14	0.2U	5U
3:1 Soil: Fluff	1	50U	0.05	1U	4U	5U
	3	2	0.05U	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.15	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	2	0.05	10	0.2U	5U
	90	4	0.08U	16	0.2U	5U
3:1 Soil: Fluff	1	50U	0.11	1U	4U	5U
	3	2	0.05U	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.005U	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	4	0.05	10	0.2U	5U
	90	1U	0.08U	5	0.2U	5U

Table B23. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (μg/L) Chromium	Copper	Lead	Zinc
Soil	1	10U	11	50U	14
	3	10U	9	50U	16
	5	10U	9	50U	9
	7	10U	14	50U	8
	14	10U	13	50U	3U
	28	11	22	50U	3U
	90	26	28	20U	4U
1:1 Soil: Fluff	1	10U	38	50U	18
	3	10	25	50U	23
	5	10U	13	50U	12
	7	10U	14	50U	9
	14	10U	34	50U	6
	28	23	55	50U	5
	90	22	64	20U	4U
3:1 Soil: Fluff	1	10U	39	50U	17
	3	15	28	50U	53
	5	10U	22	50U	9
	7	10U	22	50U	8
	14	12	40	50U	7
	28	12	57	50U	3U
	90	26	64	20U	4U
3:1 Soil: Fluff	1	10U	32	50U	29
	3	10U	30	50U	25
	5	10U	19	50U	2U
	7	10U	14	50U	4
	14	11	45	50U	5
	28	13	78	50U	3U
	90	26	71	20U	4U
3:1 Soil: Fluff	1	10U	29	50U	20
	3	14	25	50U	22
	5	10U	18	50U	15
	7	10U	12	50U	9
	14	10U	31	50U	7
	28	10	39	50U	3U
	90	26	56	20U	4U

Table B23. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (ng/L) Naphthalene	Acenaphthylene	Acenaphthene	Fluorene
Soil	1	4700U	8100U	8100U	1000U
	3	4400U	7600U	7600U	900U
	5	4600UJ	7900UJ	7900UJ	900UJ
	7	5200U	8900U	8900U	1000U
	14	1E4U	2E4U	2E4U	3000U
	28	13E3U	22E3U	22E3U	2600U
	90	1E4U	2E4U	2E4U	2600U
1:1 Soil: Fluff	1	4600U	7900U	7900U	900U
	3	4300U	7300U	7300U	900U
	5	4900UJ	8400UJ	8400UJ	1000UJ
	7	4500U	7700U	7700U	900U
	14	1E4U	3E4U	3E4U	3000U
	28	12E3U	21E3U	21E3U	2500U
	90	1E4U	2E4U	2E4U	2600U
3:1 Soil: Fluff	1	4400U	7700U	7700U	900U
	3	4400U	7500U	7500U	900U
	5	4700UJ	8100UJ	8100UJ	950UJ
	7	5100U	8800U	8800U	1000U
	14	1E4U	2E4U	2E4U	3000U
	28	12E3U	21E3U	21E3U	2500U
	90	1E4U	2E4U	2E4U	2600U
3:1 Soil: Fluff	1	4700U	8000U	8000U	900U
	3	4700U	8100U	8100U	900U
	5	5000UJ	8500UJ	8500UJ	1000UJ
	7	4600U	7900U	7900U	900U
	14	1E4U	2E4U	2E4U	3000U
	28	12E3U	20E3U	20E3U	2400U
	90	R	R	R	R
3:1 Soil: Fluff	1	4400U	7600U	7600U	900U
	3	4300U	7400U	7400U	900U
	5	4700UJ	8000UJ	8000UJ	900UJ
	7	4400U	7500U	7500U	900U
	14	1E4U	2E4U	2E4U	3000U
	28	12E3U	20E3U	20E3U	2300U
	90	1E4U	2E4U	2E4U	2600U

Table B23. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (ng/L) Phenanthrene	Anthracene	Fluoranthene	Pyrene
Soil	1	80	10J	100U	400U
	3	90	10J	100U	400U
	5	70J	10UJ	100UJ	400UJ
	7	90	10J	100U	400U
	14	200U	40U	400U	1200U
	28	200U	40U	400U	1000U
	90	200U	40U	400U	1100U
1:1 Soil: Fluff	1	140	30	100J	400U
	3	100	10J	100U	400U
	5	100J	20J	100UJ	400UJ
	7	80	10J	100U	400U
	14	200U	40U	400U	1300U
	28	200U	40U	400U	1000U
	90	200U	90	400U	1100U
3:1 Soil: Fluff	1	100	30	100U	400U
	3	90	10J	100U	400U
	5	70J	10J	100UJ	400UJ
	7	70U	10U	100U	400U
	14	200U	40U	400U	1200U
	28	200U	40U	400U	1000U
	90	200U	40U	400U	1100U
3:1 Soil: Fluff	1	200	50	100U	400U
	3	100	30	100U	400U
	5	100J	10J	100UJ	400UJ
	7	80	10J	100U	400U
	14	200J	40U	400U	1100U
	28	200J	30J	300U	1000U
	90	R	R	R	R
3:1 Soil: Fluff	1	100	20	100U	400U
	3	100	10J	640	400U
	5	70J	10UJ	100UJ	400UJ
	7	60J	10J	100U	400U
	14	200U	40U	400U	1000U
	28	200U	30U	300U	1000U
	90	200U	40U	400U	1100U

Table B23. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (ng/L) Benzo(a)-anthracene	Chrysene	Benzo(b)-fluoranthene	Benzo(k) fluoranthene
Soil	1	70U	70U	40U	10U
	3	60U	60U	40U	10U
	5	70UJ	70UJ	40UJ	10UJ
	7	70U	70U	40U	10U
	14	200U	200U	100U	40U
	28	200U	200U	100U	40U
	90	200U	200U	100U	40U
1:1 Soil: Fluff	1	70U	70U	40J	10J
	3	60U	60U	40U	10U
	5	70UJ	70UJ	40UJ	10UJ
	7	60U	60U	40U	10U
	14	200U	200U	100U	40U
	28	200U	200U	100U	40U
	90	200U	200U	100U	40U
3:1 Soil: Fluff	1	60U	60U	40U	10U
	3	60U	60U	40U	10U
	5	70UJ	70UJ	40UJ	10UJ
	7	70U	70U	40U	10U
	14	200U	200U	100U	40U
	28	200U	200U	100U	40U
	90	200U	200U	100U	40U
3:1 Soil: Fluff	1	70U	70U	40U	100J
	3	70U	70U	40U	10U
	5	70UJ	70UJ	400UJ	10UJ
	7	70U	70U	40U	10U
	14	200U	200U	100U	40U
	28	200U	200U	100U	30J
	90	R	R	R	R
3:1 Soil: Fluff	1	60U	60U	40U	10U
	3	60U	60U	40U	10U
	5	70UJ	70UJ	40UJ	10UJ
	7	60U	60U	40U	10U
	14	200U	200U	100U	40U
	28	200U	200U	100U	30U
	90	200U	200U	100U	40U

Table B23. (Continued).

		Concentration (ng/L)			
Fixed Material	Elapsed Time (Days)	Benzo(a) pyrene	Dibenzo-(a,h)anthracene	Benzo(ghi)perylene	Indeno(1,2,3-cd) pyrene
Soil	1	70U	300U	300U	100U
	3	60U	250U	250U	100U
	5	70UJ	300UJ	300UJ	100UJ
	7	70U	300U	300U	100U
	14	200U	800U	800U	400U
	28	200U	700U	700U	400U
	90	200U	800U	800U	400U
1:1 Soil: Fluff	1	70U	300U	300U	100U
	3	60U	200U	200U	100U
	5	70UJ	300UJ	300UJ	100UJ
	7	60U	300U	300U	100U
	14	200U	900U	900U	400U
	28	200U	700U	700U	400U
	90	200U	800U	800U	400U
3:1 Soil: Fluff	1	60U	300U	300U	100U
	3	60U	300U	300U	100U
	5	70UJ	300UJ	300UJ	100UJ
	7	70U	300U	300U	100U
	14	200U	800U	800U	400U
	28	200U	700U	700U	400U
	90	200U	800U	800U	400U
3:1 Soil: Fluff	1	70U	300U	300U	100U
	3	70U	300U	300U	100U
	5	70UJ	300UJ	300UJ	100UJ
	7	70U	300U	300U	100U
	14	200U	700U	700U	400U
	28	200U	700U	700U	300U
	90	R	R	R	R
3:1 Soil: Fluff	1	60U	250U	250U	100U
	3	60U	200U	200U	100U
	5	70UJ	300UJ	300UJ	100UJ
	7	60U	300U	300U	100U
	14	200U	700U	700U	400U
	28	200U	700U	700U	300U
	90	200U	700U	700U	400U

Table B23. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (µg/L)			
		PCB 1016	PCB 1221	PCB 1232	PCB 1242
Soil	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
1:1 Soil: Fluff	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
3:1 Soil: Fluff	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
3:1 Soil: Fluff	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
3:1 Soil: Fluff	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.3U	0.3U	0.3U	0.3U
	90	0.1U	0.1U	0.1U	0.1U

Table B23. (Concluded).

Fixed Material	Elapsed Time (Days)	Concentration (μg/L) PCB 1248	PCB 1254	PCB 1260	Total Phenols
Soil	1	0.3U	0.3U	0.3U	12
	3	0.3U	0.3U	0.3U	8
	5	0.3U	0.3U	0.3U	5
	7	0.3U	0.3U	0.3U	5
	14	0.3U	0.3U	0.3U	8J
	28	0.2U	0.2U	0.2U	10
	90	0.1U	0.1U	0.1U	28J
1:1 Soil: Fluff	1	0.3U	0.3U	0.3U	38
	3	0.3U	0.3U	0.3U	28
	5	0.3U	0.3U	0.3U	15
	7	0.3U	0.3U	0.3U	12
	14	0.3U	0.3U	0.3U	28J
	28	0.2U	0.2U	0.2U	30
	90	0.1U	0.1U	0.1U	45J
3:1 Soil: Fluff	1	0.3U	0.3U	0.3U	28
	3	0.3U	0.3U	0.3U	15
	5	0.3U	0.3U	0.3U	10
	7	0.3U	0.3U	0.3U	5
	14	0.3U	0.3U	0.3U	20J
	28	0.2U	0.2U	0.2U	20
	90	0.1U	0.1U	0.1U	45J
3:1 Soil: Fluff	1	0.3U	0.3U	0.3U	25
	3	0.3U	0.3U	0.3U	20
	5	0.3U	0.3U	0.3U	12
	7	0.3U	0.3U	0.3U	5
	14	0.3U	0.3U	0.3U	15J
	28	0.2U	0.2U	0.2U	20
	90	0.1U	0.1U	0.1U	40J
3:1 Soil: Fluff	1	0.3U	0.3U	0.3U	50
	3	0.3U	0.3U	0.3U	20
	5	0.3U	0.3U	0.3U	12
	7	0.3U	0.3U	0.3U	10
	14	0.3U	0.3U	0.3U	20J
	28	0.3U	0.3U	0.2U	25
	90	0.1U	0.1U	0.1U	8J

Table B24. Contaminant concentrations in ANS leachate from tar, tar-soil mixtures and blank samples

Fixed Material	Elapsed Time (Days)	Concentration (µg/L) Arsenic	Mercury	Selenium	Silver	Cadmium
Tar	1	50U	0.05	1U	4U	5U
	3	4	0.05U	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.05U	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	2	0.05	9	0.2U	5U
	90	1U	0.082	16	0.2U	5U
1:1 Tar: Soil	1	50U	0.05	1U	4U	5U
	3	1	0.05U	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.05U	1U	0.2U	5U
	14	1U	0.05U	1U	0.2U	5U
	28	2	0.05	9	0.2U	5U
	90	1U	0.08U	13	0.2U	5U
Sand Blank	1	50U	0.11	1U	4U	5U
	3	1U	0.05	1U	0.2U	5U
	5	1U	0.05U	1U	0.2U	5U
	7	1U	0.1	1U	0.2UJ	5U
	14	1U	0.05U	1U	0.2U	5U
	28	1U	0.05	5	0.2U	5U
	90	1U	0.08U	15	0.2U	5U
Blank	1	50U	0.11	1U	4U	5U
Blank	3	1	0.05U	1U	0.2U	5U
Blank	4	1	0.05U	1U	0.2U	5U
Blank	5	1U	0.05U	1U	0.2U	5U
Blank	7	1U	0.05U	1U	0.2U	5U
Blank	14	1U	0.05	1U	0.2U	5U
Blank	28	1U	0.05	2	0.2U	5U
Blank	90	1U	0.08U	1U	0.2U	5U

Table B24. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (µg/L) Chromium	Copper	Lead	Zinc
Tar	1	10U	3U	50U	14
	3	10U	3U	50U	15
	5	10U	3U	50U	7
	7	10	27	50U	25
	14	10U	3U	50U	3U
	28	10U	4	50U	3U
	90	14	4U	20U	4U
1:1 Tar: Soil	1	10U	3U	50U	14
	3	10U	3U	50U	15
	5	10U	3	50U	19
	7	10U	3U	50U	9
	14	10U	9	50U	3U
	28	10U	13	50U	4
	90	13	4	20U	4U
Sand Blank	1	10U	3U	50U	12
	3	11	3U	50U	13
	5	10U	4	50U	2
	7	10U	3U	50U	5
	14	10U	3U	50U	3U
	28	10U	8	50U	3U
	90	10U	4U	20U	4U
Blank	1	10U	3U	50U	12
Blank	3	10U	3U	50U	16
Blank	4	10U	3U	50U	16
Blank	5	10U	3U	50U	5
Blank	7	10U	3U	50U	7
Blank	14	10U	3U	50U	3U
Blank	28	10U	10	50U	3U
Blank	90	10U	4U	20U	4U

Table B24. (Continued).

Fixed Material	Elapsed Time (Days)	Concentration (ng/L) Naphthalene	Acenaphthylene	Acenaphthene	Fluorene
Tar	1	2E6	4E5U	4E5U	8E4
	3	2E6	4E5U	4E5U	1E5
	5	2E6J	4E5UJ	4E5UJ	1E5J
	7	1E6	5E5U	5E5U	1E5
	14	6E5	1E6U	1E6U	1E5
	28	10E6	2300U	2300U	9E5
	90	7E5	5E5	7E5U	8E4
1:1 Tar: Soil	1	2E6	4E5U	4E5U	8E4
	3	2E6	4E5U	4E5U	1E5
	5	4E6J	4E5UJ	4E5UJ	7E5J
	7	1E6	4E5U	4E5U	1E5
	14	5E5	1E6U	1E6U	7E4
	28	2E6	21000U	21000U	3E5
	90	4E5	3E5	5E5U	7E4
Sand Blank	1	9700	14000U	14000U	1600U
	3	4700U	8000U	8000U	900U
	5	5400UJ	9200UJ	9200UJ	1100UJ
	7	5400U	9200U	9200U	1100U
	14	1E4U	2E4U	2E4U	2000U
	28	12000U	2E4U	2E4U	2400U
	90	1E4U	2E4U	2E4U	2400U
Blank	1	4700U	8100U	8100U	1000U
Blank	3	4200U	7300U	7300U	800U
Blank	4	4400U	7600U	7600U	900U
Blank	5	5700UJ	9800UJ	9800UJ	1100UJ
Blank	7	5700U	9800U	9800U	1100U
Blank	14	1E4U	2E4U	2E4U	3000U
Blank	28	12000U	20000U	20000U	2400U
Blank	90	1E4U	2E4U	2E4U	2300U

Table B24. (Continued).

		Concentration (ng/L)			
Fixed Material	Elapsed Time (Days)	Phenanthrene	Anthracene	Fluoranthene	Pyrene
Tar	1	3E4	6000	9000	2E4U
	3	8E4	1E4	1E4	2E4U
	5	7E4J	1E4J	3E4J	2E4UJ
	7	9E4	1E4	8000U	2E4U
	14	1E5	3E4	2E4J	6E4U
	28	6E5	5E4	6E4	6E4U
	90	6E4	1E4	2E4	3E4U
1:1 Tar: Soil	1	4E4	7000	1E4	2E4U
	3	1E5	1E4	2E4	2E4U
	5	4E4J	7000J	7000UJ	2E4UJ
	7	1E5	1E5	6000U	2E4U
	14	4E4	1E4	2E4J	5E4U
	28	2E5	2E4	9000U	3E4U
	90	6E4	9000	9000U	25000U
Sand Blank	1	200	40	200U	700U
	3	100	10J	100U	400U
	5	80UJ	20UJ	200UJ	500UJ
	7	80U	20U	200U	500U
	14	200U	40U	400U	1000U
	28	200U	30U	300U	1000U
	90	200U	30U	300U	1000U
Blank	1	70U	10U	100U	400U
Blank	3	60U	10U	100U	400U
Blank	4	60U	10U	100U	400U
Blank	5	80UJ	20UJ	200UJ	500UJ
Blank	7	80U	20U	200U	500U
Blank	14	200U	40U	400U	1100U
Blank	28	200U	30U	300U	1000U
Blank	90	200U	30U	300U	1000U

Table B24. (Continued).

		Concentration (ng/L)			
Fixed Material	Elapsed Time (Days)	Benzo(a)-anthracene	Chrysene	Benzo(b)-fluoranthene	Benzo(k) fluoranthene
Tar	1	3000U	3000U	2000U	600U
	3	3200U	3200U	1900U	60U
	5	4000UJ	4000UJ	2000UJ	700UJ
	7	80U	100	50U	20J
	14	200U	500	100J	40J
	28	200U	800	200	40J
	90	7000	7000	5000	4000
1:1 Tar: Soil	1	3000U	3000U	2E4U	600U
	3	3000U	3000U	2000U	600U
	5	4000UJ	4000UJ	40UJ	40J
	7	3000U	3000U	200	50
	14	200U	200U	1100U	40U
	28	200U	500	100U	30U
	90	4100U	4100U	2500U	800J
Sand Blank	1	100U	100U	70U	20U
	3	70U	70U	40U	10U
	5	80UJ	80UJ	50UJ	20UJ
	7	80U	80U	50U	20U
	14	200U	200U	100U	40U
	28	200U	200U	100U	30U
	90	200U	200U	100U	30U
Blank	1	70U	70U	40U	10U
Blank	3	60U	60U	40U	10U
Blank	4	60U	60U	40U	10U
Blank	5	80UJ	80UJ	50UJ	20UJ
Blank	7	80U	80U	50U	20U
Blank	14	200U	200U	100U	40U
Blank	28	200U	200U	100U	30U
Blank	90	200U	200U	100U	30U

Table B24. (Continued).

		Concentration (ng/L)			
Fixed Material	Elapsed Time (Days)	Benzo(a) pyrene	Dibenzo-(a,h)anthracene	Benzo(ghi)perylene	Indeno(1,2,3-cd) pyrene
Tar	1	3000U	1E4U	1E4U	6000U
	3	3200U	1E4U	1E4U	6000U
	5	4000UJ	500J	300UJ	200J
	7	80U	300U	300U	200U
	14	200U	800U	800U	400U
	28	200J	800U	800U	400U
	90	5000	2E4U	2E4U	1E4U
1:1 Tar: Soil	1	3000U	1E4U	1E4U	6000U
	3	3000U	1E4U	1E4U	6000U
	5	250J	300UJ	300UJ	100UJ
	7	200	300U	300U	100U
	14	200U	700U	700U	400U
	28	200U	700U	700U	300U
	90	4100U	16E4U	16E4U	8000U
Sand Blank	1	100U	500U	500U	200U
	3	70U	300U	350	100U
	5	80UJ	300UJ	300UJ	200UJ
	7	80U	300U	300U	200U
	14	200U	700U	700U	400U
	28	200U	700U	700U	300U
	90	200U	700U	700U	300U
Blank	1	70U	300U	300U	100U
Blank	3	60U	200U	200U	100U
Blank	4	60U	300U	300U	100U
Blank	5	80UJ	300UJ	300UJ	200UJ
Blank	7	80U	300U	300U	200U
Blank	14	200U	700U	700U	400U
Blank	28	200U	700U	700U	300U
Blank	90	200U	700U	700U	300U

Table B24. (Continued).

		Concentration (µg/L)			
Fixed Material	Elapsed Time (Days)	PCB 1016	PCB 1221	PCB 1232	PCB 1242
Tar	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
1:1 Tar: Soil	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
Sand Blank	1	0.3U	0.3U	0.3U	0.3U
	3	0.3U	0.3U	0.3U	0.3U
	5	0.3U	0.3U	0.3U	0.3U
	7	0.3U	0.3U	0.3U	0.3U
	14	0.3U	0.3U	0.3U	0.3U
	28	0.2U	0.2U	0.2U	0.2U
	90	0.1U	0.1U	0.1U	0.1U
Blank	1	0.3U	0.3U	0.3U	0.3U
Blank	3	0.3U	0.3U	0.3U	0.3U
Blank	4	0.3U	0.3U	0.3U	0.3U
Blank	5	0.3U	0.3U	0.3U	0.3U
Blank	7	0.3U	0.3U	0.3U	0.3U
Blank	14	0.3U	0.3U	0.3U	0.3U
Blank	28	0.2U	0.2U	0.2U	0.2U
Blank	90	0.1U	0.1U	0.1U	0.1U

Table B24. (Concluded).

Fixed Material	Elapsed Time (Days)	Concentration (μg/L) PCB 1248	PCB 1254	PCB 1260	Total Phenols
Tar	1	0.3U	0.3U	0.3U	230
	3	0.3U	0.3U	0.3U	145
	5	0.3U	0.3U	0.3U	95
	7	0.3U	0.3U	0.3U	75
	14	0.3U	0.3U	0.3U	190J
	28	0.2U	0.2U	0.2U	248
	90	0.1U	0.1U	0.1U	548J
1:1 Tar: Soil	1	0.3U	0.3U	0.3U	375
	3	0.3U	0.3U	0.3U	240
	5	0.3U	0.3U	0.3U	140
	7	0.3U	0.3U	0.3U	118
	14	0.3U	0.3U	0.3U	265J
	28	0.2U	0.2U	0.2U	328
	90	0.1U	0.1U	0.1U	662J
Sand Blank	1	0.3U	0.3U	0.3U	5U
	3	0.3U	0.3U	0.3U	5U
	5	0.3U	0.3U	0.3U	5
	7	0.3U	0.3U	0.3U	5U
	14	0.3U	0.3U	0.3U	5UJ
	28	0.2U	0.2U	0.2U	5U
	90	0.1U	0.1U	0.1U	30J
Blank	1	0.3U	0.3U	0.3U	5U
Blank	3	0.3U	0.3U	0.3U	5U
Blank	4	0.3U	0.3U	0.3U	5U
Blank	5	0.3U	0.3U	0.3U	5U
Blank	7	0.3U	0.3U	0.3U	5U
Blank	14	0.3U	0.3U	0.3U	5UJ
Blank	28	0.2U	0.2U	0.2U	5U
Blank	90	0.1U	0.1U	0.1U	20J

Table B25. Concentrations in ANS leachate from wet/dry-stressed fixed cylinders

Wet/Dry Cycles	Elapsed Time (Days)	Concentration (µg/L) Arsenic	Mercury	Selenium	Silver	Cadmium
4 Cycles	3	8	0.05U	1U	0.2U	5U
	8	1U	0.05U	1U	0.2U	5U
	10	1U	0.1	1U	0.2U	5U
	12	1U	0.1	1U	0.2U	5U
	19	11	0.05U	1U	0.2U	5U
	31	11	0.05	6	0.2U	5U
	92	R	0.08UJ	R	R	R
12 Cycles	3	8	0.1	1U	0.2U	5U
	15	1U	0.05U	1U	0.2U	5U
	17	8	0.31	1U	0.2UJ	14J
	19	8	0.05U	1UJ	0.2U	5U
	27	11	0.05	3	0.2U	5U
	41	11	0.08	1U	0.2U	5U
	104	2	0.08U	1U	0.2U	6
20 Cycles	3	5	0.05U	1U	0.2U	5U
	15	1U	0.05	1U	0.2U	5U
	27	9	0.05	6	0.2U	5U
	29	2	0.05	6	0.2U	5U
	36	15	0.05U	1U	0.2U	5U
	50	8	0.086	1U	0.2UJ	5U
	112	3	0.08U	8	0.2U	5U
20 Cycles	3	7J	0.05	1U	0.2U	5U
	15	1U	0.05	1U	0.2U	5U
	27	5	0.05	4	0.2U	5U
	29	1U	0.05	6	0.2U	5U
	36	13	0.05U	1U	0.2U	11
	50	3	0.11	1U	0.2U	5
	112	7	0.08U	5	0.2UJ	5U
20 Cycles	3	6	0.1	1U	0.2U	5U
	15	1U	0.21	1U	0.2U	5U
	27	7	0.05	5	0.2U	5U
	29	2	0.2	4	0.2U	5U
	36	10	0.1	1U	0.2U	5U
	50	7	0.074U	1U	0.2U	5U
	112	4	0.08U	6	0.2U	5U

Note: All cylinders used in these tests were fixed 3:1 soil:auto fluff.

Table B25. (Continued).

		Concentration (µg/L)			
Wet/Dry Cycles	Elapsed Time (Days)	Chromium	Copper	Lead	Zinc
4 Cycles	3	22	72	50U	15
	8	25	48	50U	7
	10	10U	25	50U	6
	12	10U	183	50U	94
	19	15	142	50U	5
	31	11	34	50U	3U
	92	R	R	R	R
12 Cycles	3	25	88	50U	25
	15	49	54	50U	4
	17	17	403	50U	20
	19	11	94	50U	6
	27	11	40	50U	3U
	41	10U	3U	50U	3U
	104	18	42	20U	6
20 Cycles	3	30	78	50U	16
	15	55	64	50U	3U
	27	31	38	50U	3U
	29	13	15	50U	3U
	36	18	3U	50U	3U
	50	16	387	20U	3U
	112	13	30	20U	4U
20 Cycles	3	30	90	50U	26
	15	48	68	50U	9
	27	28	44	50U	3U
	29	10U	13	50U	3U
	36	15	3U	50U	3U
	50	14	85	20U	6
	112	13	29	20U	4U
20 Cycles	3	26	81	50U	15
	15	38	54	50U	6
	27	26	36	50U	3U
	29	10U	12	50U	3U
	36	15	3U	50U	3U
	50	14	81	20U	3U
	112	11	30	20U	4U

Table B25. (Continued).

Wet/Dry Cycles	Elapsed Time (Days)	Concentration (ng/L) Naphthalene	Acenaphthylene	Acenaphthene	Fluorene
4 Cycles	3	R	R	R	R
	8	1E4U	2E4U	2E4U	3E3U
	10	1E4U	2E4U	2E4U	3E3U
	12	1E4U	2E4U	2E4U	2E3U
	19	12000U	2E4U	2E4U	2300U
	31	13000U	22000U	22000U	2500U
	92	1E4U	2E4U	2E4U	2900U
12 Cycles	3	4600U	7900U	7900U	900U
	15	12000U	21000U	21000U	2400U
	17	12000U	21000U	21000U	2400U
	19	13000U	22000U	22000U	2600U
	27	12000U	21000U	21000U	2400U
	41	12000U	21000U	21000U	2400U
	104	1E4U	2E4U	2E4U	2400U
20 Cycles	3	R	R	R	R
	15	12000U	21000U	21000U	2400U
	27	12000U	2E4U	2E4U	2300U
	29	12000U	2E4U	2E4U	2300U
	36	11000U	19000U	19000U	2300U
	50	12000U	2E4U	2E4U	2300U
	112	1E4U	2E4U	2E4U	2400U
20 Cycles	3	4700U	8100U	8100U	900U
	15	12000U	21000U	21000U	2400U
	27	12000U	21000U	21000U	2400U
	29	12000U	2E4U	2E4U	2400U
	36	1200U	2E4U	2E4U	2400U
	50	15000U	25000U	25000U	3000U
	112	1E4U	2E4U	2E4U	2400U
20 Cycles	3	4800U	8300U	8300U	970U
	15	13000U	23000U	23000U	2700U
	27	12000U	2E4U	2E4U	2300U
	29	11000U	19000U	19000U	2300U
	36	11000U	2E4U	2E4U	2300U
	50	13000U	22000U	22000U	2500U
	112	1E4U	2E4U	2E4U	2500U

Table B25. (Continued).

Wet/Dry Cycles	Elapsed Time (Days)	Concentration (ng/L) Phenanthrene	Anthracene	Fluoranthene	Pyrene
4 Cycles	3	R	R	R	R
	8	200U	40U	400U	1000U
	10	200U	40U	400U	1200U
	12	200U	30U	300U	1000U
	19	200U	30U	300U	1000U
	31	200U	40U	400U	1000U
	92	200U	40U	400U	1200U
12 Cycles	3	90	10U	900	400U
	15	200U	30U	300U	1000U
	17	200U	30U	300U	1000U
	19	200U	40U	400U	1000U
	27	200U	30U	300U	1000U
	41	200U	30U	300U	1000U
	104	200U	30U	300U	1000U
20 Cycles	3	R	R	R	R
	15	200U	30U	300U	1000U
	27	200U	30U	300U	1000U
	29	200U	30U	300U	1000U
	36	200U	30U	300U	1000U
	50	200U	30U	300U	1000U
	112	200U	30U	300U	1000U
20 Cycles	3	90	10J	100U	500
	15	200U	30U	300U	1000U
	27	200U	30U	300U	1000U
	29	200U	30U	300U	1000U
	36	200U	30U	300U	1000U
	50	200U	40U	400U	1300U
	112	200U	30U	300U	1000U
20 Cycles	3	100	10J	100U	400U
	15	200U	40U	400U	1200U
	27	200U	30U	300U	1000U
	29	200U	30U	300U	1000U
	36	200U	30U	300U	1000U
	50	200U	40U	400U	1100U
	112	200U	40U	350U	1000U

Table B25. (Continued).

		ANS Leachate Concentration (ng/L)			
Wet/Dry Cycles	Elapsed Time (Days)	Benzo(a)-anthracene	Chrysene	Benzo(b) fluoranthene	Benzo(k) fluoranthene
4 Cycles	3	R	R	R	R
	8	200U	200U	100U	40U
	10	200U	200U	100U	40U
	12	200U	200U	100U	30U
	19	200U	200U	100U	30U
	31	200U	200U	100U	40U
	92	200U	200U	100U	40U
12 Cycles	3	70J	70U	40U	100U
	15	200U	200U	100U	30U
	17	200U	200U	100U	30U
	19	200U	200U	100U	40U
	27	200U	200U	100U	30U
	41	200U	200U	100U	30U
	104	200U	200U	100U	30U
20 Cycles	3	R	R	R	R
	15	200U	200U	100U	30U
	29	200U	200U	100U	30U
	36	200U	200U	100U	30U
	27	200U	200U	100U	30U
	50	200U	200U	100U	30U
	112	200U	200U	100U	30U
20 Cycles	3	70U	70U	40U	30
	15	200U	200U	100U	30U
	27	200U	200U	100U	30U
	29	200U	200U	100U	30U
	36	200U	200U	100U	30U
	50	200U	200U	100U	40U
	112	200U	200U	100U	30U
20 Cycles	3	70U	70U	40U	10U
	15	200U	200U	100U	40U
	27	200U	200U	100U	30U
	29	200U	200U	100U	30U
	36	200U	200U	100U	30U
	50	200U	200U	100U	40U
	112	200U	200U	100U	40U

Table B25. (Continued)

Wet/Dry Cycles	Elapsed Time (Days)	Concentration (ng/L) Benzo(a) pyrene	Dibenzo-(a,h)anthracene	Benzo(ghi)perylene	Indeno(1,2,3-cd) pyrene
4 Cycles	3	R	R	R	R
	8	200U	700U	700U	400U
	10	200U	800U	800U	400U
	12	200U	700U	700U	300U
	19	200U	700U	700U	300U
	31	200U	700U	700U	400U
	92	200U	800U	800U	400U
12 Cycles	3	70U	300U	300U	100U
	15	200U	700U	700U	300U
	17	200U	700U	700U	300U
	19	200U	700U	700U	400U
	27	200U	700U	700U	300U
	41	200U	700U	700U	300U
	104	200U	700U	700U	300U
20 Cycles	3	R	R	R	R
	15	200U	700U	700U	300U
	27	200U	700U	700U	300U
	29	8200U	700U	700U	300U
	36	200U	600U	600U	300U
	50	200U	700U	700U	300U
	112	200U	700U	700U	300U
20 Cycles	3	10U	300U	300U	100U
	15	200U	700U	700U	300U
	27	200U	700U	700U	300U
	29	200U	700U	700U	300U
	36	200U	700U	700U	300U
	50	200U	800U	800U	400U
	112	200U	700U	700U	300U
20 Cycles	3	70U	300U	300U	100U
	15	200U	800U	800U	400U
	27	200U	700U	700U	300U
	29	200U	600U	600U	300U
	36	200U	700U	700U	300U
	50	200U	700U	700U	400U
	112	200U	700U	700U	350U

Table B25. (Continued).

		Concentration (μg/L)			
Wet/Dry Cycles	Elapsed Time (Days)	PCB 1016	PCB 1221	PCB 1232	PCB 1242
4 Cycles	3	0.3U	0.3U	0.3U	0.3U
	8	0.3U	0.3U	0.3U	0.3U
	10	0.3U	0.3U	0.3U	0.3U
	12	0.3U	0.3U	0.3U	0.3U
	19	0.3U	0.3U	0.3U	0.3U
	31	0.2U	0.2U	0.2U	0.2U
	92	0.1U	0.1U	0.1U	0.1U
12 Cycles	3	0.3U	0.3U	0.3U	0.3U
	15	0.3U	0.3U	0.3U	0.3U
	17	0.3U	0.3U	0.3U	0.3U
	19	0.3U	0.3U	0.3U	0.3U
	27	0.2U	0.2U	0.2U	0.2U
	50	0.25U	0.25U	0.25U	0.25U
	104	0.10U	0.10U	0.10U	0.10U
20 Cycles	3	0.3U	0.3U	0.3U	0.3U
	15	0.3U	0.3U	0.3U	0.3U
	27	0.2U	0.2U	0.2U	0.2U
	29	0.2U	0.2U	0.2U	0.2U
	36	0.25U	0.25U	0.25U	0.25U
	50	0.25U	0.25U	0.25U	0.25U
	112	0.20U	0.20U	0.20U	0.20U
20 Cycles	3	0.3U	0.3U	0.3U	0.3U
	15	0.3U	0.3U	0.3U	0.3U
	27	0.2U	0.2U	0.2U	0.2U
	29	0.2U	0.2U	0.2U	0.2U
	36	0.25U	0.25U	0.25U	0.25U
	50	0.25U	0.25U	0.25U	0.25U
	112	0.1U	0.1U	0.1U	0.1U
20 Cycles	3	0.3U	0.3U	0.3U	0.3U
	15	0.3U	0.3U	0.3U	0.3U
	27	0.2U	0.2U	0.2U	0.2U
	29	0.2U	0.2U	0.2U	0.2U
	36	0.25U	0.25U	0.25U	0.25U
	50	0.25U	0.25U	0.25U	0.25U
	112	0.20U	0.20U	0.20U	0.20U

Table B25. (Concluded).

		Concentration (µg/L)			
Wet/Dry Cycles	Elapsed Time (Days)	PCB 1248	PCB 1254	PCB 1260	Total Phenols
4 Cycles	3	0.3U	0.3U	0.3U	68
	8	0.3U	0.3U	0.3U	45
	10	0.3U	0.3U	0.3U	15J
	12	0.3U	0.3U	0.3U	15J
	19	0.3U	0.3U	0.3U	22
	31	0.2U	0.2U	0.2U	22J
	92	0.1U	0.1U	0.1U	70
12 Cycles	3	0.3U	0.3U	0.3U	60
	15	0.3U	0.3U	0.3U	78
	17	0.3U	0.3U	0.3U	20
	19	0.3U	0.3U	0.3U	10
	27	0.2U	0.2U	0.2U	5U
	41	0.25U	0.25U	0.25U	5
	104	0.10U	0.10U	0.1U	8
20 Cycles	3	0.3U	0.3U	0.3U	42
	15	0.3U	0.3U	0.3U	68
	27	0.2U	0.2U	0.25U	58
	29	0.2U	0.2U	0.2U	12
	36	0.25U	0.25U	0.2U	5U
	50	0.25U	0.25U	0.25U	5U
	112	0.20U	0.20U	0.2U	5J
20 Cycles	3	0.3U	0.3N		90
	15	0.3U	0.3U	0.3U	85
	27	0.2U	0.2U	0.25U	70
	29	0.2U	0.2U	0.2U	15
	36	0.25U	0.25U	0.2U	5U
	50	0.25U	0.25U	0.25U	5U
	112	0.1U	0.1U	0.1U	5J
20 Cycles	3	0.3U	0.3U	0.3U	68
	15	0.3U	0.3U	0.25U	70
	27	0.2U	0.2U	0.25U	62
	29	0.2U	0.2U	0.3U	15
	36	0.25U	0.25U	0.2U	5U
	50	0.25U	0.25U	0.2U	5U
	112	0.20U	0.20U	0.2U	5J